SB4319E00
Jan. 2008

Service Manual

4TNV98 & 4TNE98 Diesel Engine

D20S-5, D25S-5, D30S-5, D33S-5, D35C-5
(4TNV98 : EM0Q3, EM0Q4, EM0Q5)
D20S-5, D25S-5, D30S-5, D33S-5, D35C-5
(4TNE98 : EM0QC, EM0QD, EM0QE)
D20G, D25G, D30G
(4TNE98)

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Read and understand all safety precautions and warnings before operating or performing lubrication, maintenance and repair on this product.

Basic safety precautions are listed in the “Safety” section of the Service or Technical Manual. Additional safety precautions are listed in the “Safety” section of the owner/operation/maintenance publication.
Specific safety warnings for all these publications are provided in the description of operations where hazards exist. WARNING labels have also been put on the product to provide instructions and to identify specific hazards. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons. Warnings in this publication and on the product labels are identified by the following symbol.

⚠ WARNING

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.
Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

DOOSAN cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by DOOSAN is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product. Obtain the complete and most current information before starting any job. DOOSAN dealers have the most current information available.

Section 1. GENERAL SERVICE INFORMATION

Component Identification 7
Location of Labels 8
Engine Nameplate (Typical) 8
Emission Control Regulations 8
EPA / ARB Regulations - USA Only 8
Emission Control Labels 9
The 97/68/EC Directive Certified Engines 9
Engine Family 9
Function of Major Engine Components 10
Function of Cooling System Components 11
Diesel Fuel 12
Diesel Fuel Specifications 12
Filling The Fuel Tank 13
Priming the Fuel System 15
Engine Oil 16
Engine Oil Specifications 16
Engine Oil Viscosity 16
Checking Engine Oil 17
Adding Engine Oil 17
Engine Oil Capacity (Typical) 17
Engine Coolant 18
Engine Coolant Specifications 19
Filling Radiator with Engine Coolant 19
Engine Coolant Capacity (Typical) 20
Specifications 20
Description of Model Number 20
Engine General Specifications 21
Principal Engine Specifications 22
4TNV98 EPA Tier 2 22
4TNE98 EPA Tier 3 23
Engine Service Standards 24
Tightening Torques for Standard Bolts and Nuts 25
Abbreviations and Symbols 27
Abbreviations. 27
Symbols 27
Unit Conversions 28
Unit Prefixes 28
Units of Length 28
Units of Volume 28
Units of Mass 28
Units of Force 28
Units of Torque 28
Units of Pressure 28
Units of Power 28
Units of Temperature 28

Section 2. PERIODIC MAINTENANCE

Before You Begin Servicing 29
Introduction 40
The Importance of Periodic Maintenance 40
Performing Periodic Maintenance 40
Yanmar Replacement Parts 40
Required EPA / ARB Maintenance-USA Only 40
EPA / ARB Installation Requirements-USA Only 40
Periodic Maintenance Schedule 41
Periodic Maintenance Procedures 43
Drain Fuel Filter / Water Separator 43
4TNE98 For D25S-5 Only 43
Daily 45
After Initial 50 Hours of Operation 45
Every 50 Hours of Operation 48
Every 250 Hours of Operation 51
Every 500 Hours of Operation 54
Every 1000 Hours of Operation 59
Every 1500 Hours of Operation 61
Every 2000 Hours of Operation 62

Section 3. ENGINE

Before You Begin Servicing 63
Introduction 66
Cylinder Head Specifications 66
Adjustment Specifications 66
Cylinder Head 66
Intake / Exhaust Valve and Guide Cont... 67
Push Rod 68
Rocker Arm and Shaft 68
Valve Spring 68
Camshaft and Timing Gear Train Specifications 68
Camshaft 68
Idler Gear Shaft and Bushing 69
Timing Gear Backlash 69
Crankshaft and Piston Specifications 70
Crankshaft 70
Thrust Bearing 70
Piston 71
Connecting Rod 72
Tappet 72
Cylinder Block Specifications 73
Cylinder Block 73
Special Torque Chart 73
Torque for Bolts and Nuts 73
Special Service Tools 75

Measuring Instruments..... 77
Cylinder Head..... 80
Cylinder Head Components..... 80
Disassembly of 4-Valve Cylinder Head ... 82
4TNE98 Engine..... 87
Disassembly of Cylinder Head..... 89
Cleaning of Cylinder Head Components . 92
Inspection of Cylinder Head Components93
Reassembly of Cylinder Head 98
Measuring and Adjusting Valve Clearance..... 104
4TNE98 Engine..... 105
4TNV98 Engine..... 106
Crankshaft and Camshaft Components..... 109
Disassembly of Engine 111
Disassembly of Camshaft and Timing Components.....111
Disassembly of Crankshaft and Piston Components..... 116
Inspection of Crankshaft and Camshaft Components..... 120
Honing and Boring..... 126
Reassembly of Crankshaft and Piston Components..... 127
Reassembly of Camshaft and Timing Components..... 136
Final Reassembly of Engine..... 138

Section 4. FUEL SYSTEM

Before You Begin Servicing..... 139
4TNV98 ENGINE..... 141
Introduction 141
Fuel Injection Pump..... 141
Stop Solenoid..... 142
Cold Start Device..... 142
Trochoid Fuel Pump 142
Fuel System Specifications 143
Special Torque Chart 143
Test and Adjustment Specifications..... 144
Special Service Tools 145
Measuring Instruments..... 145
Fuel System Diagram 146
Fuel System Components..... 147
4-Valve Cylinder Head..... 147
Fuel Injection Pump 148
Removal of Fuel Injection Pump 148
Installation of Fuel Injection Pump 152
Checking and Adjusting Fuel Injection Timing.... 157
Determining the Fuel Injection Timing Specification..... 157
Checking Fuel Injection Timing..... 158
Adjusting Fuel Injection Timing..... 161
Fuel Injectors..... 163
Removal of Fuel Injectors..... 163
Testing of Fuel Injectors 164
Disassembly and Inspection of Fuel Injectors..... 165
Adjusting Fuel Injector Pressure..... 166
Reassembly of Fuel Injectors 167
Installation of the Fuel Injectors..... 167
4TNE98 ENGINE..... 168
Fuel System Special Torque Chart..... 168
Measuring Instruments..... 168
Fuel System Components..... 169
Fuel System Components 170
Structure And Operation Of Fuel Injection Pump..... 171
Overview..... 172
Plunger Operation..... 175
Process..... 176
Reverse Rotation Prevention Mechanism 178
Fuel Injection Volume Adjustment Mechanism 178
Delivery Valve Assembly 179
Delivery Valve Holder with Damping Valve 179
All - Speed Governor 180
At Start of Engine..... 182
During Idling..... 183
At Full-Load Maximum Speed Control .. 184
At No-Load Maximum Speed Control ... 185
Full-Load Position Adjustment Mechanism 186
Structure And Operation Of Timer 187
Standard Type Automatic Timer..... 187
Magnetic Valve (Stop Solenoid)..... 188
Removal Of Fuel Injection Pump..... 189
Installation Of The Fuel Injection Pump..... 192
Checking / Adjustment Of Fuel Injection Timing. 194
Servicing The Fuel Injectors..... 196
Removal of the Fuel Injectors..... 196
Inspection and Testing of the Fuel Injectors 197
Judgement Criteria on Atomization Condition 199
Installation of Fuel Injectors..... 200

Section 5. COOLING SYSTEM

Before You Begin Servicing 201
Introduction 203
Cooling System Diagram 203
Engine Coolant Pump Components 204
Engine Coolant System Check 205
Engine Coolant Pump 205
Removal of Engine Coolant Pump 205
Disassembly of Engine Coolant Pump 207
Cleaning and Inspection 207
Reassembly of Engine Coolant Pump 208
Installation of Engine Coolant Pump 208

Section 6. LUBRICATION SYSTEM

Before You Begin Servicing 210
Introduction 212
Oil Pump Service Information 212
Lubrication System Diagram 214
Checking Engine Oil Pressure 215
Trochoid Oil Pump 215
Oil Pump Components 215
Disassembly of Oil Pump 216
Cleaning and Inspection 216
Reassembly of Oil Pump 217

Section 7. STARTER MOTOR

Before You Begin Servicing 219
Introduction 221
Starter Motor Information 221
Starter Motor Specifications 222
Starter Motor Troubleshooting 223
Starter Motor Components 224
Starter Motor 225
Removal of Starter Motor 225
Disassembly of Starter Motor 225
Cleaning and Inspection 227
Reassembly of Starter Motor 232
Check Pinion Projection Length 233
No-Load Test 234
Installation of Starter Motor 234

Section 8. TROUBLESHOOTING

Special Service Tools 235
Troubleshooting By Measuring Compression Pressure 236
Compression Pressure Measurement Method 236
Quick Reference Table For Troubleshooting 239
Troubleshooting Charts 240
Wiring Diagram 243

Section 1. GENERAL SERVICE INFORMATION

Component Identification

Figure 4-1a, Figure 4-1b shows where the major engine components are located.

4TNV98 ENGINE

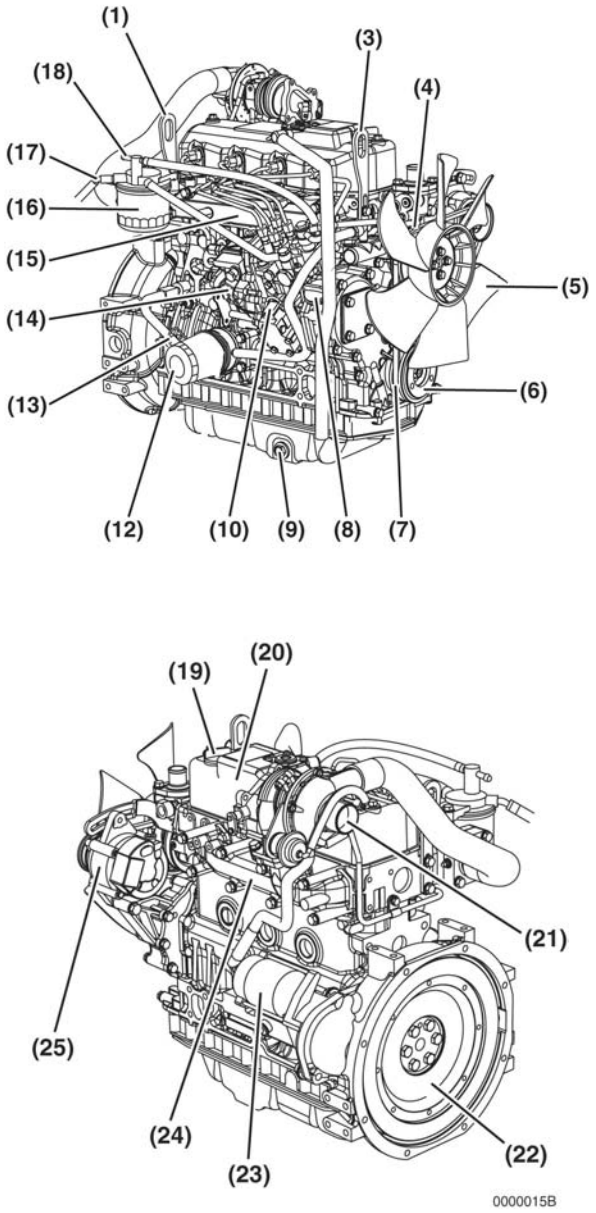


Figure 4-1a

(1) Lifting Eye (Flywheel End).
(3) Lifting Eye (Engine Cooling Fan End).
(4) Engine Coolant Pump. (5) Engine Cooling Fan.
(6) Crankshaft V-Pulley. (7) V-Belt.
(8) Side Filler Port (Engine Oil). (9) Drain Plug (Engine Oil).
(10) Fuel Injection Pump. (12) Engine Oil Filter.
(13) Dipstick (Engine Oil) (14) Governor Lever.
(15) Intake Manifold. (16) Fuel Filter.
(17) Fuel Inlet. (18) Fuel Return to Fuel Tank.
(19) Top Filler Port (Engine Oil). (20) Rocker Arm Cover.
(21) Air Intake Port (From Air Cleaner).
(22) Flywheel. (23)Starter Motor.
(24) Exhaust Manifold. (25) Alternator.

4TNE98 ENGINE

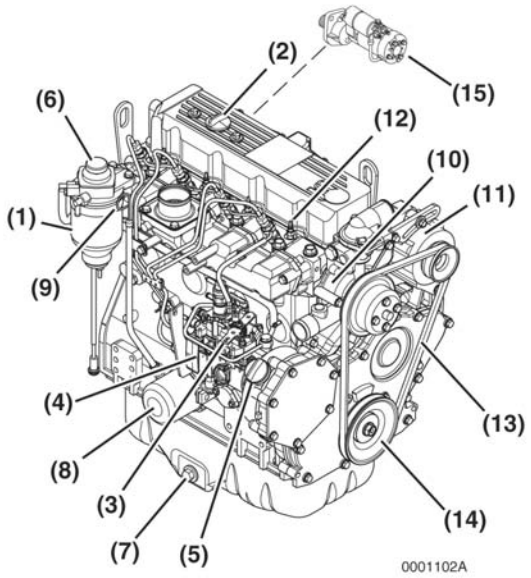


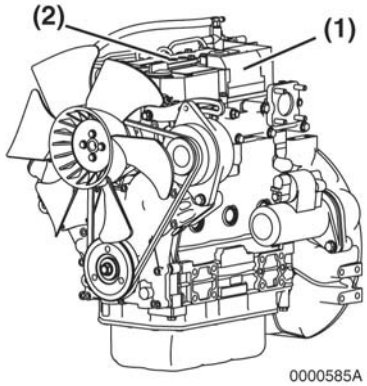
Figure 4-1b

(1) Fuel Filter / Water Separator
(2)Top Filler Port (Engine Oil)
(3) Governor Lever
(4) Fuel Injection Pump
(5) Side Filler Port (Engine Oil)
(6) Fuel Priming Pump
(7) Drain Plug (Engine Oil)
(8) Engine Oil Filter
(9) Dipstick (EngineOil)
(10) Engine Coolant Pump
(11) Alternator
(12) Glow Plug
(13) V-Belt
(14) Crankshaft V-Pulley
(15) Starter Motor

Location of Labels

Figure 4-2 shows the location of regulatory and safety labels on Yanmar TNV & TNE series engines.

4TNE98 ENGINE



4TNV98 ENGINE

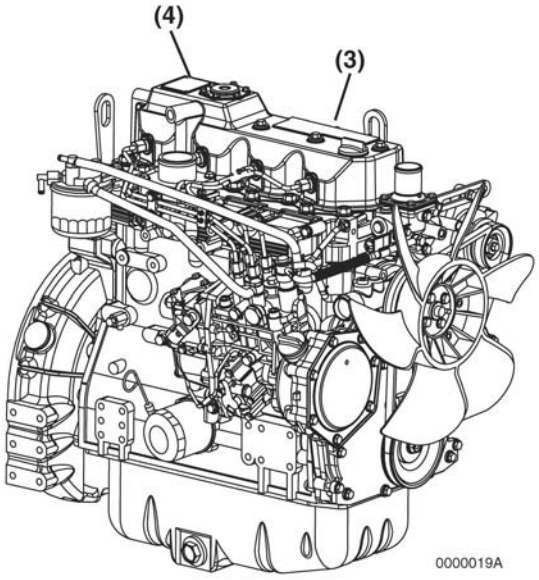
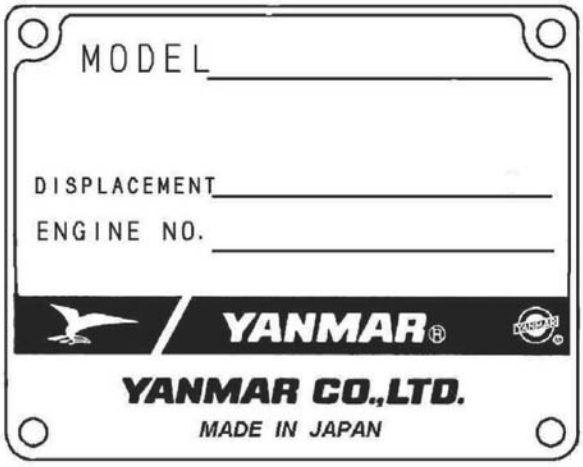


Figure 4-2

The typical location of the emission control information label shown **(Figure 4-2 (2), (3)).**

The typical location of the engine nameplate is shown **(Figure 4-2 (1), (4)).**

Engine Nameplate (Typical)



Emission Control Regulations

EPA / ARB Regulations - USA Only

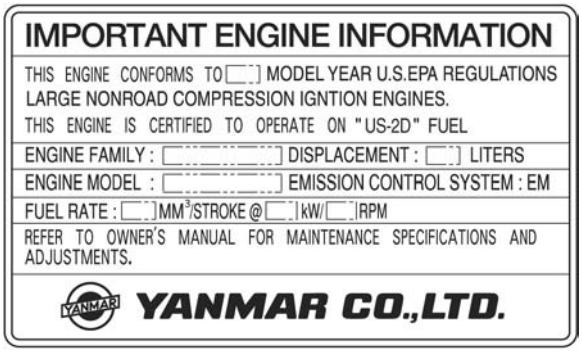
Yanmar engines meet Environmental Protection Agency (EPA) (U. S. Federal) emission control standards as well as the California Air Resources Board (ARB, California) regulations. Only engines that conform to ARB regulations can be sold in the State of California.

Refer to the specific EPA / ARB installation (page 40) and maintenance (page 40) in the Periodic Maintenance Schedule section of this manual.

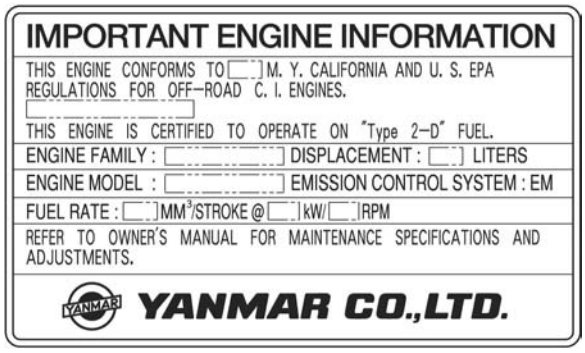
Emission Control Labels

Since emission control regulations are being issued on a global basis, it is necessary to identify which regulations a particular engine complies with. We have listed several different types of labels you might find on your engine.

EPA / ARB Labels


IMPORTANT ENGINE INFORMATION
THIS ENGINE CONFORMS TO [ ] MODEL YEAR U.S.EPA REGULATIONS LARGE NONROAD COMPRESSION IGNTION ENGINES.
THIS ENGINE IS CERTIFIED TO OPERATE ON "US-2D" FUEL
ENGINE FAMILY : [ ] DISPLACEMENT : [ ] LITERS
ENGINE MODEL : [ ] EMISSION CONTROL SYSTEM : EM
FUEL RATE : [ ] MM³/STROKE @ [ ] kW/ [ ] RPM
REFER TO OWNER'S MANUAL FOR MAINTENANCE SPECIFICATIONS AND ADJUSTMENTS.
YANMAR CO.,LTD.

(EPA) Greater than or Equal to 50 HP SAE (37kW)

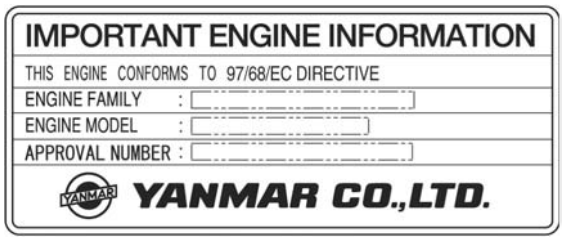

IMPORTANT ENGINE INFORMATION
THIS ENGINE CONFORMS TO [ ] M. Y. CALIFORNIA AND U. S. EPA REGULATIONS FOR OFF-ROAD C. I. ENGINES.
[ ]
THIS ENGINE IS CERTIFIED TO OPERATE ON "Type 2-D" FUEL.
ENGINE FAMILY : [ ] DISPLACEMENT : [ ] LITERS
ENGINE MODEL : [ ] EMISSION CONTROL SYSTEM : EM
FUEL RATE : [ ] MM³/STROKE @ [ ] kW/ [ ] RPM
REFER TO OWNER'S MANUAL FOR MAINTENANCE SPECIFICATIONS AND ADJUSTMENTS.
YANMAR CO.,LTD.

(EPA and ARB)

The 97/68/EC Directive Certified Engines

The engines described in this manual have been certified by the 97/68/EC Directive.

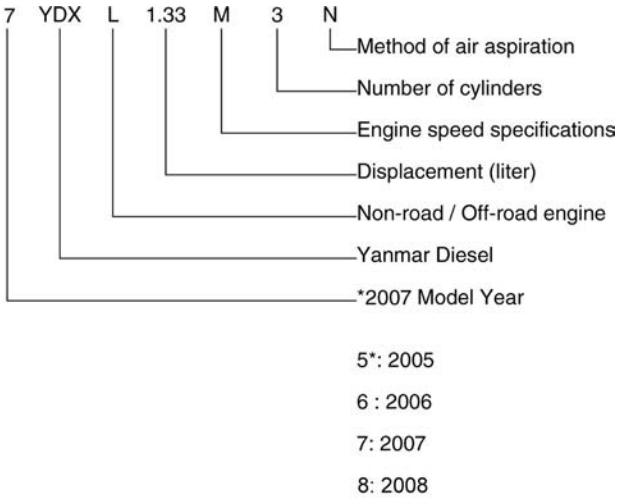
To identify the engines that meet this certification, the 97/68/EC emission control label is affixed on the engines


IMPORTANT ENGINE INFORMATION
THIS ENGINE CONFORMS TO 97/68/EC DIRECTIVE
ENGINE FAMILY : [ ]
ENGINE MODEL : [ ]
APPROVAL NUMBER : [ ]
YANMAR CO.,LTD.

(97/68/EC)

Engine Family

The EPA / ARB labels and the 97/68/EC label all have an Engine Family field. The following is an explanation of the Engine Family designation:



Function of Major Engine Components

Components	Functions
Air Cleaner	The air cleaner prevents airborne contaminants from entering the engine. Since the air cleaner is application specific, it must be carefully selected by an application engineer. It is not part of the basic engine package as shipped from the Yanmar factory. Periodic replacement of the air cleaner filter element is necessary. See the Periodic Maintenance Schedule on page 39 for the replacement frequency.
Dipstick (Engine Oil)	The alternator is driven by a V-belt which is powered by the crankshaft V-pulley. The alternator supplies electricity to the engine systems and charges the battery while the engine is running.
Dipstick (Engine Oil)	The engine oil dipstick is used to determine the amount of engine oil in the crankcase.
Electric Fuel Pump (If Equipped)	The electric fuel pump makes sure there is a constant supply of diesel fuel to the fuel injection pump. The electric fuel pump is electro-magnetic and runs on 12 VDC. An electic fuel pump may be installed as an option or as standard equipment. Standard equipment may vary based on engine model and specification. If an electic fuel pump is installed, turn the key switch to the ON position for 10 to 15 seconds to prime the fuel system.
Engine Oil Filter	The engine oil filter removes contaminants and sediments from the engine oil. Periodic replacement of the engine oil filter is necessary. See the Periodic Maintenance Schedule on page 39 for the replacement frequency.
Engine Oil Cooler (If Equipped)	The engine oil cooler helps to keep the engine oil cool. Engine coolant from the cooling system is circulated through an adapter at the base of the engine oil filter assembly and then returned to the coolant pump inlet.
Fuel Filter	The fuel filter removes contaminants and sediments from the diesel fuel. Periodic replacement of the fuel filter is necessary. See the Periodic Maintenance Schedule on page 39 for the replacement frequency. **Please note that the word “diesel” is implied throughout this manual when the word “fuel” is used.**
Fuel Filter/ Water Separator	The fuel filter / water separator removes contaminants, sediments and water from the diesel fuel going to the fuel filter. This is a required component of the fuel system. This is standard equipment with every engine. The separator is installed between the fuel tank and the electric fuel pump. Periodically drain the water from the fuel filter / water separator.
Fuel Priming Lever (If Equipped)	If the unit has a mechanical fuel pump, a fuel priming lever on the mechanical fuel pump primes the fuel system. The fuel sytem needs to be primed before you start the engine for the first time, if you run out of fuel, or if fuel system service is performed. To prime the fuel system, operate the fuel priming lever until the cup in the fuel filter is full of fuel.
Fuel Tank	The fuel tank is a reservoir that holds diesel fuel. When the fuel leaves the fuel tank it goes to the fuel filter / water separator. Next the fuel is pumped to the fuel filter by the electric fuel pump. Then the fuel goes to the fuel injection pump. Since the fuel is used to keep the fuel injection pump cool and lubricated, more fuel than necessary enters the injection pump. When the injection pump pressure reaches a preset value, a relief valve allows the excess fuel to be returned back to the fuel tank. The fuel tank is a required engine component.
Side and Top Filler Port (Engine Oil)	You can fill the crankcase with engine oil from either the side or the top filler port depending upon which one is most convenient.
Starter Motor	The starter motor is powered by the battery. When you turn the key switch in the operator’s console to the START position, the starter motor engages with the ring gear installed on the flywheel and starts the flywheel in motion.

Function of Cooling System Components

Components	Functions
Cooling System	The TNV engine is liquid-cooled by means of a cooling system. The cooling system consists of a radiator, radiator cap, engine cooling fan, engine coolant pump,thermostat, and reserve tank. **Note that all cooling system components are required for proper engine operation. Since some of the components are application specific, they must be carefully selected by an application engineer. The application specific items are not part of the basic engine package as shipped from the Yanmar factory.**
Engine Cooling Fan	The engine cooling fan is driven by a V-belt which is powered by the crankshaft V-pulley. The purpose of the engine cooling fan is to circulate air through the radiator.
Engine Coolant Pump	The engine coolant pump circulates the engine coolant through the cylinder block and the cylinder head and returns the engine coolant to the radiator.
Radiator	The radiator acts as a heat exchanger. As the engine coolant circulates through the cylinder block it absorbs heat. The heat in the engine coolant is dissipated in the radiator. As the engine cooling fan circulates air through the radiator, the heat is transferred to the air.
Radiator Cap	The radiator cap controls the cooling system pressure. The cooling system is pressurized to raise the boiling point of the engine coolant. As the engine coolant temperature rises, the system pressure and the coolant volume increases. When the pressure reaches a preset value, the release valve in the radiator cap opens and the excess engine coolant flows into the reserve tank. As the engine coolant temperature is reduced, the system pressure and volume is reduced and the vacuum valve in the radiator cap opens allowing the engine coolant to flow from the reserve tank back into the radiator.
Reserve Tank	The reserve tank contains the overflow of engine coolant from the radiator. If you need to add engine coolant to the system, add it to the reserve tank; not the radiator.
Thermostat	A thermostat is placed in the cooling system to prevent the engine coolant from circulating into the radiator until the engine coolant temperature reaches a preset temperature. When the engine is cold, no engine coolant flows through the radiator. Once the engine reaches its operating temperature, the thermostat opens and allows the engine coolant to flow through the radiator. By letting the engine warm up as quickly as possible, the thermostat reduces engine wear, deposits and emissions.

Diesel Fuel

Diesel Fuel Specifications

Diesel fuel should comply with the following specifications. The table lists several worldwide specifications for diesel fuels.

.

Diesel Fuel Specification	Location
No. 2-D, No. 1-D, ASTM D975-94	USA
EN590:96	European Union
ISO 8217 DMX	International
BS 2869-A1 or A2	United Kingdom
JIS K2204 Grade No. 2	Japan
KSM-2610	Korea
GB252	China

Additional Technical Fuel Requirements

- The fuel cetane number should be equal to 45 or higher.
- The sulfur content must not exceed 0.5% by volume. Less than 0.05% is preferred.
- Bio-Diesel fuels. See Bio-Diesel Fuels on page 4-9.
- NEVER mix kerosene, used engine oil, or residual fuels with the diesel fuel.
- The water and sediment in the fuel should not exceed 0.05% by volume.
- Keep the fuel tank and fuel-handling equipment clean at all times.
- Poor quality fuel can reduce engine performance and / or cause engine damage.
- Fuel additives are not recommended. Some fuel additives may cause poor engine performance. Consult your Yanmar representative for more information.
- The ash content must not exceed 0.01% by volume.
- The carbon residue content must not exceed 0.35% by volume. Less than 0.1% is preferred.
- The total aromatics content should not exceed 35% by volume. Less than 30% is preferred.
- The PAH (polycyclic aromatic hydrocarbons) content should be below 10% by volume.
- The metal content of Na, Mg, Si, and Al should be equal to or lower than 1 mass ppm. (Test analysis method JPI-5S-44-95)
- Lubricity: The wear mark of WS1.4 should be Max. 0.018 in (460 µm) at HFRR test.

Bio-Diesel Fuels

In Europe and in the United States, as well as some other countries, non-mineral oil based fuel resources such as RME (Rapeseed Methyl Ester) and SOME (Soybean Methyl Ester), collectively known as FAME (Fatty Acid Methyl Esters), are being used as extenders for mineral oil derived diesel fuels.

Yanmar approves the use of bio-diesel fuels that do not exceed a blend of 5% (by volume) of FAME with 95% (by volume) of approved mineral oil derived diesel fuel. Such bio-diesel fuels are known in the marketplace as B5 diesel fuels.

These B5 diesel fuels must meet certain requirements.

1. The bio-fuels must meet the minimum specifications for the country in which they areused.

- In Europe, bio-diesel fuels must comply with the European Standard EN14214.
- In the United States, bio-diesel fuels must comply with the American Standard ASTM D-6751.

2. Bio-fuels should be purchased only from recognized and authorized diesel fuel suppliers.

Precautions and concerns regarding the use of bio-fuels:

1. Free methanol in FAME may result in corrosion of aluminum and zinc FIE components.

2. Free water in FAME may result in plugging of fuel filters and increased bacterial growth.

3. High viscosity at low temperatures may result in fuel delivery problems, injection pump seizures, and poor injection nozzle spray atomization.

4. FAME may have adverse effects on some elastomers (seal materials) and may result in fuel leakage and dilution of the engine lubricating oil.

5. Even bio-diesel fuels that comply with a suitable standard as delivered, will require additional care and attention to maintain the quality of the fuel in the equipment or other fuel tanks. It is important to maintain a supply of clean, fresh fuel. Regular flushing of the fuel system, and / or fuel storage containers, may be necessary.

6. The use of bio-diesel fuels that do not comply with the standards as agreed to by the diesel engine manufacturers and the diesel fuel injection equipment manufacturers, or biodiesel fuels that have degraded as per the precautions and concerns above, may affect the warranty coverage of your engine.

Filling The Fuel Tank

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.

NEVER refuel with the engine running.

Wipe up all spills immediately.

Keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.

NEVER overfill the fuel tank.

Fill the fuel tank. Store any containers

containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

Be sure to place the diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.

NEVER place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

Before you operate the engine, check for fuel leaks. Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.

Failure to comply will result in death or serious injury.

⚠ CAUTION

Only use diesel fuels recommended by Yanmar for the best engine performance, to prevent engine

damage and to comply with EPA / ARB warranty requirements.

Only use clean diesel fuel.

NEVER remove the primary strainer (if equipped) from the fuel tank filler port. If removed, dirt and debris could get into the fuel system causing it to clog.

Note that a typical fuel tank is shown. The fuel tank on your equipment may be different.

1. Clean the area around the fuel cap **(Figure 4-3, (1)).**

2. Remove the fuel cap **(Figure 4-3, (1))** from the fuel tank **(Figure 4-3, (2)).**

3. Observe the fuel level sight gauge **(Figure 4-3, (3))** and stop fueling when the gauge shows the fuel tank is full. NEVER overfill the fuel tank.

4. Replace the fuel cap **(Figure 4-3, (1))** and hand tighten. Over-tightening the fuel cap will damage it.

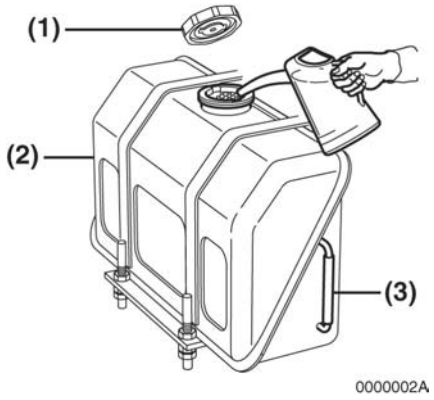


Figure 4-3

Priming the Fuel System

The fuel system needs to be primed under certain conditions.

• Before starting the engine for the first time.

• After running out of fuel and fuel has been added to the fuel tank.

• After fuel system maintenance such as changing the fuel filter and draining the fuel filter / water separator, or replacing a fuel system component.

To prime the fuel system on engines equipped with an electric fuel pump:

1. Place an approved container under the air bleed port.

2. Loosen the air bleed port 2 or 3 turns.

3. Turn the key to the ON position for 10 to 15 seconds or until the fuel coming out of the air bleed port is free of bubbles.

4. Tighten the air bleed port.

5. Wipe up any spills and properly dispose of fuel.

6. NEVER use the starter motor to crank the engine in order to prime the fuel system. This may cause the starter motor to overheat and damage the coils, pinion and/or ring gear.

To prime the fuel system on engines not equipped with an electric fuel system:

1. Place an approved container under the air bleed port.

2. Loosen the air bleed port **(Figure4-4, (1))** 2 or 3 turns.

3. Operate the fuel priming pump **(Figure4-4, (2))** until the fuel coming out of the air bleed port is free of bubbles.

4. Tighten the air bleed port.

5. Wipe up any spills and properly dispose of fuel.

6. NEVER use the starter motor to crank the engine in order to prime the fuel system. This may cause the starter motor to overheat and damage the coils, pinion and/or ring gear.

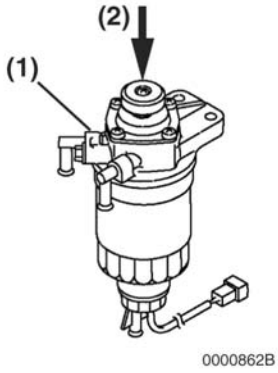


Figure 4-4

Engine Oil

⚠ CAUTION

Only use the engine oil specified.

Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

Engine Oil Specifications

Use an engine oil that meets or exceeds the following guidelines and classifications:

Service Categories

- API Service Categories CD or higher
- ACEA Service Categories E-3, E-4, and E-5
- JASO Service Category DH-1

Definitions

- API Classification (American Petroleum Institute)
- ACEA Classification (Association des Constructeurs Européens d'Automobilies)
- JASO (Japanese Automobile Standards Organization)

NOTE:

- Be sure the engine oil, engine oil storage containers, and engine oil filling equipment arefree of sediment and water.
- Change the engine oil after the first 50 hours of peration and then every 500 hours thereafter.
- Select the oil viscosity based on the ambient temperature where the engine is being operated. See the SAE Service Grade Viscosity Chart **(Figure 4-4a)**
- Yanmar does not recommend the use of engine oil “additives.”

Additional Technical Engine Oil Requirements:

The engine oil must be changed when the Total Base Number (TBN) has been reduced to 1.0 mgKOH /g test method; JIS K-201-5.2-2 (HCI), ASTM D4739 (HCI).

Engine Oil Viscosity

Select the appropriate engine oil viscosity based on the ambient temperature and use the SAE Service Grade Viscosity Chart in **Figure 4-4a.**

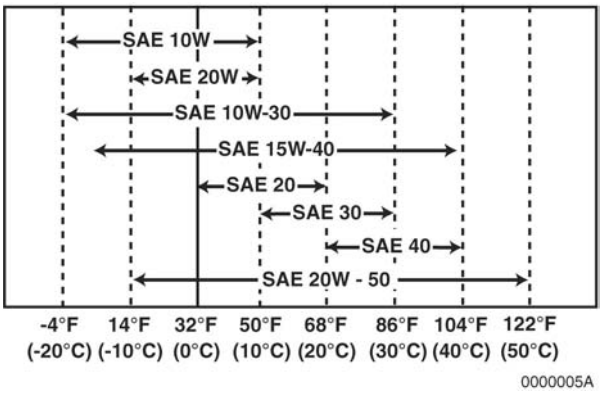


Figure 4-4a

Checking Engine Oil

1. Make sure the engine is level.

2. Remove the dipstick **(Figure 4-5, (1))** and wipe it with clean cloth.

3. Fully reinsert the dipstick.

4. Remove the dipstick. The oil level should be between the upper **(Figure 4-5, (2))** and lower **(Figure 4-5, (3))** lines on the dipstick.

5. Fully reinsert the dipstick.

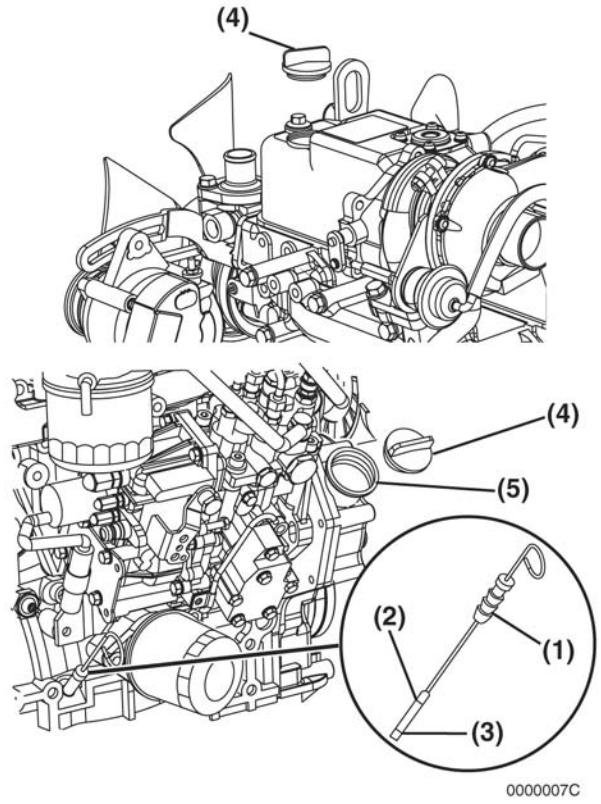


Figure 4-5

Adding Engine Oil

1. Make sure the engine is level.

2. Remove the oil cap **(Figure 4-5, (4)).**

3. Add the indicated amount of engine oil at the top or the side engine oil filler port **(Figure 4-5, (5)).**

4. Wait three minutes and check the oil level.

5. Add more oil if necessary.

6. Reinstall the oil cap **(Figure 4-5, (4))** and hand-tighten. Over-tightening may damage the cap.

Engine Oil Capacity (Typical)

NOTE: These are the engine oil capacities associated with a “deep standard” oil pan. The oil capacity will vary dependant upon which optional oil pan is used. Refer to the operation manual provided by the driven machine manufacturer for the actual engine oil capacity of your machine.

The following are the engine oil capacities for various Yanmar engines.

Engine Model	Dipstick Upper Limit / Lower Limit
4TNV98	11.1 / 6.3 qt (10.5 / 6.0 L)
4TNE98	9.7 / 7.6 qt (9.2 / 7.2 L)

Engine Coolant

⚠ DANGER

SCALD HAZARD!

NEVER remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

ALWAYS check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.

⚠ WARNING

BURN HAZARD!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.

⚠ CAUTION

COOLANT HAZARD!

Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.

CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

Engine Coolant Specifications

Use a Long Life Coolant (LLC) or an Extended Life Coolant (ELC) that meets or exceeds the following guidelines and specifications:

Additional Technical Coolant Specifications:

• ASTM D6210, D4985 (US)

• JIS K-2234 (Japan)

• SAE J814C, J1941, J1034 or J2036 (International)

Alternative Engine Coolant

If an Extended or Long Life Coolant is not available, alternatively, you may use an ethylene glycol or propylene glycol based conventional coolant (green).

Notes:

• ALWAYS use a mix of coolant and water. NEVER use water only.

• Mix the coolant and water per the mixing instructions on the coolant container.

• Water quality is important to coolant performance. Yanmar recommends that soft, distilled, or demineralized water be used to mix with coolants.

• NEVER mix extended or long life coolants and conventional (green) coolants.

• NEVER mix different types and / or colors of extended life coolants.

• Replace the coolant every 1000 engine hours or once a year.

Filling Radiator with Engine Coolant

Fill the radiator and reserve tank as follows. This procedure is for filling the radiator for the first time or refilling it after it is flushed. Note that a typical radiator is illustrated **(Figure 4-6).**

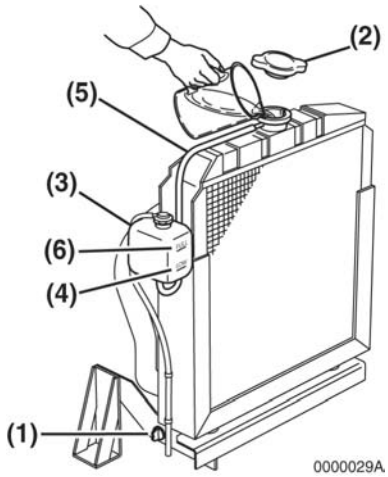


Figure 4-6

1. Check to be sure the radiator drain plug isinstalled and tightened or the drain cock**(Figure 4-6, (1))** is closed. Also make sure thecoolant drain plug **(Figure 4-7, (1))** in thecylinder block is closed or the oil coolant hoses**(Figure 4-8, (1))** are installed at the oil cooler.

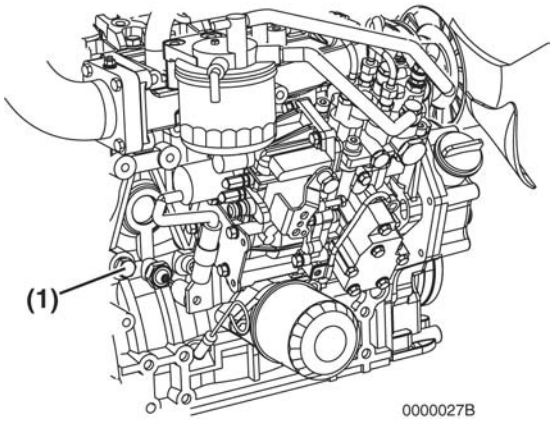


Figure 4-7

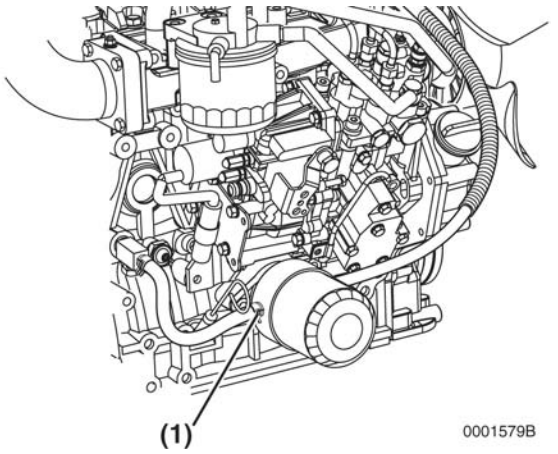


Figure 4-8

2. Remove the radiator cap **(Figure 4-6, (2))** by turning it counter-clockwise about 1/3 of a turn.

3. Pour the engine coolant slowly into the radiator until it is even with the lip of the engine coolant filler port. Make sure that air bubbles do not develop as you fill the radiator.

4. Reinstall the radiator cap **(Figure 4-6, (2)).**Align the tabs on the back side of the radiator cap with the notches on the engine coolant filler port. Press down and turn the cap clockwise about 1/3 of a turn.

5. Remove the cap on the reserve tank **(Figure 4-6**, **(3)),** and fill it to the LOW (COLD) mark **(Figure** 4-6, (4)) with engine coolant. Reinstall the cap.

6. Check the hose **(Figure 4-6, (5))** that connects the reserve tank **(Figure 4-6, (3))** to the radiator. Be sure it is securely connected and there are no cracks or damage. If the hose is damaged, the engine coolant will leak out instead of going into the reserve tank.

7. Run the engine until it is at operating temperature. Check the level of engine coolant in the reserve tank. When the engine is running and the engine coolant is at normal temperature, the coolant level in the tank should be at the FULL (HOT) mark **(Figure 4-6, (6)).** If the engine coolant is not at the FULL (HOT) mark **(Figure 4-6, (6)),** add additional engine coolant to the reserve tank to bring the level to the FULL (HOT) mark.

Engine Coolant Capacity (Typical)

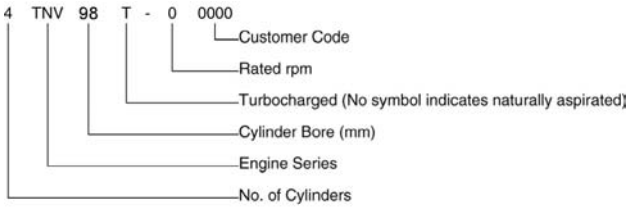
NOTE: The capacities listed are for the engineonly without a radiator. Refer to theoperation manual provided by the drivenmachine manufacturer for the actualengine coolant capacity on yourmachine.

The following are the engine coolant capacities for various Yanmar engines.

Engine Model	Engine Coolant Capacity
4TNV98	4.4 qt (4.2 L)
4TNE98	4.4 qt (4.2 L)

Specifications

Description of Model Number



When ordering parts or making an inquiry about the engine you are working on, be sure to include the complete model and serial numbers as shown on the engine nameplate. See Location of Labels on page 8.

Engine General Specifications

Type	Vertical In-line, Water Cooled, 4-Cycle Diesel Engine	
Combustion System	4TNV98	Direct Injection
	4TNE98	Indirect Injection
Starting System	Electric Starting	
Cooling System	Radiator	
Lubricating System	Forced Lubrication with Trochoid Pump	
PTO Position	Flywheel End	
Direction of Rotation	Counterclockwise Viewed from the Flywheel End	

NOTE: The information described in Principal Engine Specifications is for a “standard” engine. To obtain the information for the engine installed in your driven machine, please refer to the manual provided by the driven machine manufacturer. Engine rating conditions are as follows (SAE J1349, ISO 3046/1):

- Atmospheric Condition: Room temperature 77°F (25°C), Atmospheric pressure 29.53 in Hg (100 kPa, 750 mm Hg), Relative humidity 30%
- Fuel Temperature at Fuel Injector Pump Inlet: 104°F (40°C)
- With Cooling Fan, Air Cleaner, Muffler: Yanmar Standard
- After Engine Break-In Period; Output Allowable Deviation: ± 3%
- 1 PS = 0.7355 kW
- 1 hp SAE (Society of Automotive Engineers) = 0.7457 kW

Principal Engine Specifications

4TNV98 EPA Tier 2

Engine Model	4TNV98	
Version	VM (SDF)	
Type	Vertical In-line Diesel Engine	
Combustion System	Direct Injection	
Aspiration	Natural	
No. of Cylinders	4	
Bore × Stroke	3.858 x 4.331 in. (98 x 110 mm)	
Displacement	202.502 cu in. (3.319 L)	
Max. Rated Output (Net)	RPM	2200
	hp SAE	61.2
	kW	45.6
	PS	62.0
High Idling	RPM	2400±25
Engine Weight (Dry) with Flywheel Housing	518.2 lb (235 kg)	
PTO Position	Flywheel End (Option)	
Direction of Rotation	Counterclockwise Viewed from Flywheel End	
Cooling System	Liquid-Cooled with Radiator	
Lubricating System	Forced Lubrication with Trochoid Pump	
Normal Oil Pressure at Rated Engine Speed	42 - 57 psi (0.29 - 0.39 MPa, 2.96 - 3.98 kgf/cm²)	
Normal Oil Pressure at Low Idle Speed	8.5 psi (0.06 MPa, 0.6 kgf/cm²)or greater	
Starting System	Electric Starting - Starter Motor: DC12V, 3.1 hp (2.3 kW)**	
	Alternator: DC12V, 40A**	
	Recommended Battery Capacity: 12V, 64 Amp-Hour (5h rating)**	
Dimensions (L × W × H)*	28.31 x 19.61 x 29.21 in. (719 x 498 x 742 mm)	
Engine Oil Pan	11.1 / 6.3 qt (10.5 / 6.0 L) (Dipstick Upper Limit / Lower Limit)	
Engine Coolant Capacity	1.1 gal (4.2 L) Engine Only	
Standard Cooling Fan	16.14 in. (410 mm) O.D., 6 Blade Pusher-Type**	

* Engine specifications without radiator

** May vary depending on application.

*** Engine oil capacity for a “Deep Standard” oil pan. Refer to the operation manual provided by the driven machine manufacturer for the actual engine oil capacity of your machine.

4TNE98 EPA Tier 3

Engine Model	4TNE98 EPA Tier 3	
Version	VM (BQDF(C))	
Type	Vertical Inline Diesel Engine	
Combustion System	Indirect Injection, No Turbocharger	
Aspiration	Natural	
No. of Cylinders	4	
Bore × Stroke	3.86 x 4.33 in. (98 x 110 mm)	
Displacement	202.5 cu in. (3.319 L)	
∗∗Max. Rated Output (Gross)	RPM (min^{-1})	2300
	hp SAE	58.6
	kW	43.7
	PS	59.4
High Idling Speed (Bare Engine)	2625±25	
Low Idling Speed (Bare Engine)	850±25 rpm	
Engine Weight (Dry) ∗	496 lb (235 kg)	
PTO Position	Flywheel Side	
Direction of Rotation	Counterclockwise Viewed From Flywheel Side	
Cooling System	Liquid-Cooled With Radiator	
Lubricating System	Forced Lubrication With Trochoid Pump At normal operating speeds, oil pressure is: 42-57 psi (0.29 - 0.39 MPa; 3.0 – 4.0 kgf/cm²) At idle, oil pressure is: No less than 18.5 psi (0.13 Mpa; 1.3kgf/cm²)	
Starting System	Electric Starting - Starter Motor: DC12V, 3.1 hp (2.3 kW)	
	Alternator: DC12V, 80A	
	Recommended Battery Capacity: 12V, 622 CCA (Cold Cranking Amps)	
Dimensions (L × W × H)*	28.0 x 20.3 x 29.8 in. (710 x 516 x 758 mm)	
Engine Oil Pan Capacity	9.7 / 7.6 qt (9.2 / 7.2 L) (Dipstick Upper Limit / Lower Limit)	
Engine Coolant Capacity	1.11 gal (4.2 L) Engine Only	

* Engine Specifications Without Radiator, Muffler, and Air Cleaner.
** The Intake and Exhaust condition of Max. Rated output are
Air Intake Restriction : 250mmAq
Exhaust Gas Restriction : 1000mmAq
***The detail specifications are refer to the Specification document which is agreed between both engineering.

Engine Service Standards

Inspection Item		Standard	Limit	Reference page
Intake / Exhaust Valve Clearance		0.006 - 0.010 in. (0.15 - 0.25 mm)	-	See Measuring and Adjusting Valve Clearance on page 104
Fuel Injection Timing	4TNV98	See Checking and Adjusting Fuel Injection Timing on page 157.		
	4TNE98	8.5°±1° ATDC	-	With Plunger Lifted 0.039 in (1mm)
Fuel Injection Pressure	4TNV98	See Test and Adjustment Specifications on page 144.		
	4TNE98	1711-1842 psi (11.8 - 12.7 Mpa; 120 - 130 kgf / cm²)	-	-
Compression Pressure at 250 rpm 250 min⁻¹)	4TNV98	483 - 513 psi (3.33 - 3.53 MPa; 34 - 36 kgf / cm²)	384 - 414 psi (2.65 - 2.85 MPa; 27 - 29 kgf / cm²)	See Troubleshooting By Measuring Compression Pressure on page 236
	4TNE98	425 - 428 psi (2.93 – 2.95 MPa; 29 - 31 kgf / cm²)	341 psi (2.35 MPa; 24 kgf / cm²)	-
Deviation Between Cylinders		29 - 43 psi (0.2 - 0.3 MPa; 2 - 3 kgf/cm²)	-	-
Oil Pressure Switch Operating Pressure		5.8 - 8.8 psi (0.04 - 0.06 MPa; 0.4 - 0.6 kgf / cm²)	-	-
Lubricating Oil Pressure	Max.(when cold)	86 psi (0.59 MPa; 6.0 kgf / cm²)	-	-
	At rated Output	42 - 57 psi (0.29 - 0.39 MPa; 2.96 - 3.98 kgf / cm²)	-	-
	When idling	8.5 psi (0.06 MPa; 0.6 kgf / cm²) or greater	-	-
Thermostat		Valve Opening Temperature	Full Opening Lift Temperature	See Thermostat on page 207
	Option	157°F - 163°F (70°C - 73°C)	0.32 in (8 mm) or Above 185°F (85°C)	
	Standard	176°F - 183°F (80°C - 84°C)	0.39 in (10 mm) or above 203°F (95°C)	

Tightening Torques for Standard Bolts and Nuts

Use the correct amount of torque when you tighten the fasteners on the machine. Applying excessive torque may damage the fastener or component and not enough torque may cause a leak or component failure.

CAUTION

The tightening torque in the Standard Torque Chart (see General Service Information section) should be applied only to the bolts with a "7" head. (JIS strength classification: 7T)

Apply 60% torque to bolts that are not listed.

Apply 80% torque when tightened to aluminum alloy.

Item	Nominal Thread Diameter x Pitch	Tightening Torque	Remarks
Hexagon Bolt (7T) and Nut	M6 x 1.0 mm	7 - 9 ft·lb (87 -104 in·lb, 9.8 -11.8 N·m, 1.0 -1.2 kgf·m)	Use 80% of the value at left when the tightening part is aluminum. Use 60% of the value at left for 4T bolts and lock nuts.
	M8 x 1.25 mm	17 - 21 ft·lb (200 - 251 in.·lb, 22.6 - 28.4 N·m, 2.3 - 2.9 kgf·m)	
	M10 x 1.5 mm	33 - 40 ft·lb (44.1 - 53.9 N·m, 4.5 - 5.5 kgf·m)	
	M12 x 1.75 mm	58 - 72 ft·lb (78.4 - 98.0 N·m, 8.0 - 10 kgf·m)	
	M14 x 1.5 mm	94 - 108 ft·lb (127.5 - 147.1 N·m, 13 - 15 kgf·m)	
	M16 x 1.5 mm	159 - 174 ft·lb (215.7- 235.4 N·m, 22 – 24 kgf·m)	
PT PLug	1/8 mm	7 ft·lb (87 in.·lb, 9.8 N·m, 1.0 kgf·m)	
	1/4 mm	14 ft·lb (173 in.·lb, 19.6 N·m, 2.0 kgf·m)	
	3/8 mm	22 ft·lb (29.4 N·m, 3.0 kgf·m)	
	1/2 mm	43 ft·lb (58.8 N·m, 6.0 kgf·m)	

Item	Nominal Thread Diameter x Pitch	Tightening Torque	Remarks
Pipe Joint Bolt	M8	9 - 12 ft·lb (112 - 148 in.·lb, 12.7 - 16.7 N·m, 1.3 - 1.7 kgf·m)	.
	M10	14 - 19 ft·lb (173 - 225 in.·lb, 19.6 - 18.734 N·m, 2.0 - 3.5 kgf·m)	
	M12	18 - 25 ft·lb (24.5 - 34.3 N·m, 2.5 - 3.5 kgf·m)	
	M14	29 - 36 ft·lb (39.2 - 49.0 N·m, 4.0 5.0 kgf·m)	
	M16	36 - 43 ft·lb (49.0 - 58.8 N·m, 5.0 - 6.0 kgf·m)	

NOTE: Torque values shown in this manual are for clean, non-lubricated fasteners unless otherwise specified.

Abbreviations and Symbols

Abbreviations.

A	ampere
AC	alternating current
ACEA	Association des Constructeurs Européens d'Automobilies
Ah	ampere-hour
API	American Petroleum Institute
ARB	Air Resources Board
ATDC	after top dead center
BDC	bottom dead center
BTDC	before top dead center
°C	degree Celsius
CARB	California Air Resources Board
CCA	cold cranking amp
cfm	cubic feet per minute
cm	centimeter
cm³	cubic centimeter
cm³/min	cubic centimeter per minute
cu in.	cubic inch
D	diameter
DC	direct current
DI	direct injection
DVA	direct volt adapter
EPA	Environmental Protection Agency
ESG	electronic speed governor
°F	degree Fahrenheit
fl oz	fluid ounce (U.S.)
fl oz/min	fluid ounce (U.S.) per minute
ft	foot
ft-lb	foot pound
ft-lbf/min	foot pound force per minute
g	gram
gal	gallon (U.S.)
gal/hr	gallon (U.S.) per hour
gal/min	gallon (U.S.) per minute
GL	gear lubricant
hp	horsepower (U.S.)
hr	hour
I.D.	inside diameter
ID	identification
IDI	indirect injection
in.	inch
in.Aq	inches Aqueous (water)
in.Hg	inches Mercury
in.-lb	inch pound
j	joule
JASO	Japanese Automobile Standards Organization
k	kelvin
kg	kilogram
kgf/cm²	kilogram force per square centimeter
kgf/m	kilogram force per meter
km	kilometers
kPa	kilopascal
kW	kilowatt
L	liter
L/hr	liter per hour
lb	pound
lbf	pound force
m	meter
mL	milliliter
mm	millimeter
mmAq	millimeter Aqueous (water)
MPa	megapascal
mV	millivolt
N	newton
N·m	newton meter
No.	number
O.D.	outside diameter
oz	ounce
Pa	pascal
PS	horsepower (metric)
psi	pound per square inch
qt	quart (U.S.)
R	radius
rpm	revolutions per minute
SAE	Society of Automotive Engineers
sec.	second
t	short ton 2000 lb
TBN	total base number
TDC	top dead center
V	volt
VAC	volt alternating current
VDC	volt direct current
W	watt

Symbols

°	degree
+	plus
-	minus
±	plus or minus
Ω	ohm
µ	micro
%	percent

Unit Conversions

Unit Prefixes

Prefix	Symbol	Power
mega	M	x 1,000,000
kilo	k	x 1,000
centi	c	x 0.01
milli	m	x 0.001
micro	μ	x 0.000001

Units of Length

Mile	x	1.6090	= km
ft	x	0.3050	= m
in.	x	2.5400	= cm
in.	x	25.4000	= mm
km	x	0.6210	= mile
m	x	3.2810	= ft
cm	x	0.3940	= in.
mm	x	0.0394	= in.

Units of Volume

gal (U.S.)	x	3.78540	= L
qt (U.S.)	x	0.94635	= L
cu in.	x	0.01639	= L
cu in.	x	16.38700	= mL
fl oz(U.S.)	x	0.02957	= L
fl oz(U.S.)	x	29.57000	= mL
cm^3	x	1.00000	= mL
cm^3	x	0.03382	=floz(U.S.)

Units of Mass

lb	x	0.45360	= kg
oz	x	28.35000	= g
kg	x	2.20500	= lb
g	x	0.03527	= oz

Units of Force

lbf	x	4.4480	= N
lbf	x	0.4536	= kgf
N	x	0.2248	= lbf
N	x	0.1020	= kgf
kgf	x	2.2050	= lbf
kgf	x	9.8070	= N

Units of Torque

ft-lb	x	1.3558	= N·m
ft-lb	x	0.1383	= kgf/m
in.-lb	x	0.1130	= N·m
in.-lb	x	0.0115	= kgf/m
kgf/m	x	7.2330	= ft-lb
kgf/m	x	86.8000	= in.-lb
kgf/m	x	9.8070	= N·m
N·m	x	0.7376	= ft-lb
N·m	x	8.8510	= in.-lb
N·m	x	0.1020	= kgf/m

Units of Pressure

psi	x	0.0689	= bar
psi	x	6.8950	= kPa
psi	x	0.0703	= kg/cm^2
bar	x	14.5030	= psi
bar	x	100.0000	= kPa
bar	x	29.5300	=inHg(60°F)
kPa	x	0.1450	= psi
kPa	x	0.0100	= bar
kPa	x	0.0102	= kg/cm^2
kg/cm^2	x	98.0700	= psi
kg/cm^2	x	0.9807	= bar
kg/cm^2	x	14.2200	= kPa
in.Hg (60°)	x	0.0333	= bar
in.Hg (60°)	x	3.3770	= kPa
in.Hg (60°)	x	0.0344	= kg/cm^2
mmAq	x	0.0394	= in.Aq

Units of Power

hp (metric or PS)	x	0.9863201	= hp SAE	
hp (metric or PS)	x	0.7354988	= kW	
hp SAE	x	1.0138697	=hp(metric or PS)	
hp SAE	x	0.7456999	= kW	
kW	x	1.3596216	=hp(metric or PS)	
kW		x	1.3410221	= hp SAE

Units of Temperature

°F = (1.8 x °C) + 32

°C = 0.556 x (°F - 32)

Section 2. PERIODIC MAINTENANCE

Before You Begin Servicing

⚠ DANGER

EXPLOSION HAZARD!

NEVER check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.

If the electrolyte is frozen, slowly warm the battery before you recharge it.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Only use the key switch to start the engine.

NEVER jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.

Failure to comply will result in death or serious injury.

⚠ DANGER

SCALD HAZARD!

NEVER remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

ALWAYS check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.

NEVER refuel with the engine running.

Wipe up all spills immediately.

Keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.

NEVER overfill the fuel tank.

Fill the fuel tank. Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

Before you operate the engine, check for fuel leaks. Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

NEVER remove the fuel cap with the engine running.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

Be sure to place the diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.

NEVER place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

NEVER use diesel fuel as a cleaning agent.

Failure to comply will result in death or serious injury.

⚠ DANGER

CRUSH HAZARD!

When you need to transport an engine for repair, have a helper assist you to attach it to a hoist and load it on a truck.

NEVER stand under a hoisted engine. If the hoist mechanism fails, the engine will fall on you, causing death or serious injury.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

Place an approved container under the air bleed port when you prime the fuel system. Never use a shop rag to catch the fuel. Wipe up any spills immediately. ALWAYS close the air bleed port after you complete priming the system.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you open the air bleed port.

If the unit has an electric fuel pump, turn the key switch to the ON position for 10 to 15 seconds, or until the fuel coming out of the air bleed port is free of bubbles, to allow the electric fuel pump to prime the system.

If the unit has a mechanical fuel pump, operate the fuel priming pump several times until the fuel coming out of the air bleed port is free of bubbles.

Failure to comply will result in death or serious injury.

⚠ WARNING

EXHAUST HAZARD!

NEVER operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.

NEVER block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.

Make sure that all connections are tightened to specifications after repair is made to the exhaust system.

Failure to comply could result in death or serious injury.

⚠ WARNING

SEVER HAZARD!

Keep hands and other body parts away from moving/rotating parts such as the cooling fan, flywheel or PTO shaft.

Wear tight-fitting clothing and keep your hair short or tie it back while the engine is running.

Remove all jewelry before you operate or service the machine.

NEVER start the engine in gear. Sudden movement of the engine and/or machine could cause death or serious personal injury.

NEVER operate the engine without the guards in place.

Before you start the engine make sure that all bystanders are clear of the area.

Keep children and pets away while the engine is operating.

Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.

Failure to comply could result in death or serious injury.

⚠ WARNING

SUDDEN MOVEMENT HAZARD!

Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.

Failure to comply could result in death or serious injury.

⚠ WARNING

BURN HAZARD!

Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.

Failure to comply could result in death or serious injury.

⚠ WARNING

ALCOHOL AND DRUG HAZARD!

NEVER operate the engine while you are under the influence of alcohol or drugs.

NEVER operate the engine when you are feeling ill.

Failure to comply could result in death or serious injury.

⚠ WARNING

EXPOSURE HAZARD!

Wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.

NEVER wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving/rotating parts such as the cooling fan, flywheel or PTO shaft.

ALWAYS tie back long hair when you are working near moving/rotating parts such as a cooling fan, flywheel, or PTO shaft.

NEVER operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the alert signals.

Failure to comply could result in death or serious injury.

⚠ WARNING

BURN HAZARD!

Batteries contain sulfuric acid. NEVER allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. ALWAYS wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and / or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.

Failure to comply could result in death or serious injury.

⚠ WARNING

HIGH-PRESSURE HAZARD!

Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.

NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard. Have your authorized Yanmar industrial engine dealer or distributor repair the damage.

Failure to comply could result in death or serious injury.

⚠ WARNING

SHOCK HAZARD!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.

⚠ WARNING

ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it.

NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.

Failure to comply could result in death or serious injury.

⚠ WARNING

BURN HAZARD!

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

ALWAYS wear eye protection.

Failure to comply could result in death or serious injury.

⚠ WARNING

BURN HAZARD!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.

⚠ CAUTION

COOLANT HAZARD!

Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

CAUTION

Only use diesel fuels recommended by Yanmar for the best engine performance, to prevent engine damage and to comply with EPA/ARB warranty requirements.

Only use clean diesel fuel.

NEVER remove the primary strainer (if equipped) from the fuel tank filler port. If removed, dirt and debris could get into the fuel system causing it to clog.

CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap/dipstick and the surrounding area before you remove the cap.

NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and/or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

CAUTION

NEVER attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the diesel fuel injection quantity control.

Modifications may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may void its warranty. Be sure to use Yanmar genuine replacement parts.

CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

- **Avoid operating in extremely dusty conditions.**
- **Avoid operating in the presence of chemical gases or fumes.**
- **Avoid operating in a corrosive atmosphere such as salt water spray.**
- **NEVER install the engine in a floodplain unless proper precautions are taken to avoid being subject to a flood.**
- **NEVER expose the engine to the rain.**

CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

- **The standard range of ambient temperatures for the normal operation of Yanmar engines is from +5°F (-15°C) to +113°F (+45°C).**
- **If the ambient temperature exceeds +113°F (+45°C) the engine may overheat and cause the engine oil to break down.**
- **If the ambient temperature is below +5°F (-15°C) the engine will be hard to start and the engine oil may not flow easily.**
- **Contact your authorized Yanmar industrial engine dealer or distributor if the engine will be operated outside of this standard temperature range.**

CAUTION

NEVER hold the key in the START position for longer than 15 seconds or the starter motor will overheat.

CAUTION

For maximum engine life, Yanmar recommends that when shutting the engine down, you allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.

CAUTION

NEVER use an engine starting aid such as ether. Engine damage will result.

CAUTION

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than (IDI = 25°, DI = 30°) in any direction or if an engine runs for short periods of time (less than three minutes) at an angle greater than (IDI = 30°, DI = 35°) in any direction, engine oil may enter the combustion chamber causing excessive engine speed and white exhaust smoke. This may cause serious engine damage.

CAUTION

New Engine Break-in:

- **On the initial engine start-up, allow the engine to idle for approximately 15 minutes while you check for proper engine oil pressure, diesel fuel leaks, engine oil leaks, coolant leaks, and for proper operation of the indicators and/or gauges.**
- **During the first hour of operation, vary the engine speed and the load on the engine. Short periods of maximum engine speed and load are desirable. Avoid prolonged operation at minimum or maximum engine speeds and loads for the next four to five hours.**
- **During the break-in period, carefully observe the engine oil pressure and engine temperature.**
- **During the break-in period, check the engine oil and coolant levels frequently.**

CAUTION

NEVER engage the starter motor while the engine is running. This may damage the starter motor pinion and/or ring gear.

CAUTION

It is important to perform daily checks.

Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.

CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

CAUTION

Protect the air cleaner, turbocharger (if equipped) and electric components from damage when you use steam or high-pressure water to clean the engine.

CAUTION

NEVER overfill the engine with engine oil.

ALWAYS keep the oil level between the upper and lower lines on the oil cap/dipstick.

CAUTION

NEVER use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19 686 mmAq) or a wire brush to clean the radiator fins. Radiator fins damage easily.

CAUTION

NEVER attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the machine and shorten its life. If the idle speed limit screws require adjustment, see your authorized Yanmar industrial engine dealer or distributor.

CAUTION

Establish a periodic maintenance plan according to the engine application and make sure you perform the required periodic maintenance at the intervals indicated. Failure to follow these guidelines will impair the engine's safety and performance characteristics, shorten the engine's life and may affect the warranty coverage on your engine.

See Yanmar Limited Warranty in Warranty Section.

Consult your authorized Yanmar dealer or distributor for assistance when checking items marked with a.

CAUTION

If the fuel filter/water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter/water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter/water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.

CAUTION

When the engine is operated in dusty conditions, clean the air cleaner element more frequently.

NEVER operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.

CAUTION

The maximum air intake restriction, in terms of differential pressure measurement, must not exceed 0.90 psi (6.23 kPa; 635 mmAq). Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

Introduction

This section of the Service Manual describes the procedures for proper care and maintenance of the engine.

The Importance of Periodic Maintenance

Engine deterioration and wear occurs in proportion to length of time the engine has been in service and the conditions the engine is subject to during operation. Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.

Performing Periodic Maintenance

⚠ WARNING

EXHAUST HAZARD!

NEVER operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.

NEVER block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.

Make sure that all connections are tightened to specifications after repair is made to the exhaust system.

Failure to comply could result in death or serious injury.

Perform periodic maintenance procedures in an open, level area free from traffic. If possible, perform the procedures indoors to prevent environmental conditions, such as rain, wind, or snow, from damaging the machine.

Yanmar Replacement Parts

Yanmar recommends that you use genuine Yanmar parts when replacement parts are needed. Genuine replacement parts help ensure long engine life.

Required EPA / ARB Maintenance-USA Only

To maintain optimum engine performance and compliance with the Environmental Protection Agency (EPA) Regulations Non-road Engines and the California Air Resources Board (ARB, California), it is essential that you follow the Periodic Maintenance Schedule on page 41 and Periodic Maintenance Procedures on page 43.

EPA / ARB Installation Requirements-USA Only

The following are the installation requirements for the EPA / ARB. Unless these requirements are met, the exhaust gas emissions will not be within the limits specified by the EPA and ARB.

Maximum Exhaust Gas Restriction shall be:

- 4TNV98 : 2.22 psi (15.3 kPa; 1560mm Aq) or less
- 4TNE98 : 8.53 psi (58.8 kPa; 6000mm Aq)

Maximum air intake restriction shall be 0.90 psi (6.23 kPa; 635 mm Aq) or less. Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

Periodic Maintenance Schedule

Daily and periodic maintenance is important to keep the engine in good operating condition. The following is a summary of maintenance items by periodic maintenance intervals. Periodic maintenance intervals vary depending on engine application, loads, diesel fuel and engine oil used and are hard to establish definitively. The following should be treated only as a general guideline.

⚠ CAUTION

Establish a periodic maintenance plan according to the engine application and make sure you perform the required periodic maintenance at the intervals indicated. Failure to follow these guidelines will impair the engine's safety and performance characteristics, shorten the engine's life and may affect the warranty coverage on your engine.

See Yanmar Limited Warranty in Warranty Section.

Consult your authorized Yanmar dealer or distributor for assistance when checking items marked with a.

○:Check ◇:Replace

System	Check Item	Daily	Periodic Maintenance Interval					
			Every 50 hours	Every 250 hours	Every 500 hours	Every 1000 hours	Every 1500 hours	Every 2000 hours
Cooling System	Check and Refill Engine Cool	○						
	Check and Clean Radiator Fins			○				
	Check Engine Coolant Temp. Indicator	○						
	Check and Adjust Cooling Fan V-Belt		○1st time	○ 2nd and after				
	Drain, Flush and Refill Cooling System with New Coolant					◇ or every year whichever comes first		
Cylinder Head	Adjust Intake / Exhaust Valve Clearance					○		
	Lap Intake / Exhaust Valve Seats							○
Electrical Equipment	Check Indicators	○						
	Check Battery		○					
Engine Oil	Check Engine Oil Level	○						
	Check Engine Oil Pressure Indicator	○						
	Drain and Fill Engine Oil		◇1st time		◇ 2nd and after			
	Replace Engine Oil Filter							
Engine Speed Control	Check and Adjust Governor Lever and Engine Speed Control	○		○				
Emission Control Warranty	Inspect, Clean and Test Fuel Injectors						○	
	Inspect Crankcase Breather System						○	
Fuel	Check and Refill Fuel Tank Level	○						
	Check Fuel Filter Indicator	○						
	Drain Fuel Tank			○				
	Drain Fuel Filter / Water Separator		○					
	Check Fuel Filter / Water Separator	○						
	Clean Fuel Filter / Water Separator				○			
	Replace Fuel Filter				◇			
Hoses	Replace Fuel System and Cooling System Hoses							○ or every 2 years
Intake and Exhaust	Clean or Replace Air Cleaner Element			○	◇			
Complete Engine	Overall Visual Check Daily	○						

NOTE: These procedures are considered normal maintenance and are performed at the owner's expense.

Periodic Maintenance Procedures

Daily

Perform the following procedures daily.

- Drain Fuel Filter / Water Separator
- Check Fuel Hoses and Engine Coolant Hoses

Drain Fuel Filter / Water Separator

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- **Diesel fuel is extremely flammable and explosive under certain conditions.**
- **When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.**
- **NEVER use a shop rag to catch the fuel. Vapors from the rag are extremely flammable and explosive.**
- **Wipe up any spills immediately.**
- **Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.**
- **Failure to comply will result in death or serious injury.**

0000009en.

4TNE98 For D25S-5 Only

⚠ WARNING

HIGH PRESSURE HAZARD!

- **Avoid skin contact with high pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high pressure fuel spray obtain prompt medical treatment.**
- **NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard. Have your authorized Yanmar industrial engine dealer or distributor repair the damage.**
- **Failure to comply could result in death or serious injury.**

0000008en.

⚠ CAUTION

If no water drips when the fuel filter/water separator drain cock is opened, loosen the air vent screw on the top of the fuel filter/water separator by using a screwdriver to turn it counterclockwise 2-3 turns.This may occur if the fuel filter / water separator is positioned higher than the fuel level in the fuel tank. After draining the fuel filter/water separator, be sure to tighten the air vent screw.

0000025en.

⚠ CAUTION

Be responsible to the environment.

Follow these procedures for hazardous waste disposal. Failure to follow these procedures may seriously harm the environment.

- **Follow the guidelines of the EPA or other governmental agency for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.**
- **NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground or into ground water or waterways.**

0000013en.

NEVER wait until the scheduled periodic maintenance if the fuel filter indicator comes on.

The fuel filter / water separator contains a sensor to detect the amount of water and contaminants. This sensor sends a signal to an indicator to alert the operator.

Drain the fuel filter / water separator as follows:

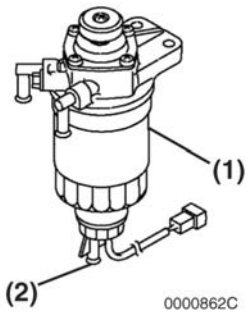


Figure 5-1

1. Position an approved container under the fuel filter / water separator **(Figure5-1, (1))** to collect the contaminants.
2. Loosen the drain cock **(Figure5-1, (2))** at the bottom of the fuel filter / water separator. Drain any water collected inside.
3. Hand tighten the drain cock.
4. Be sure to prime the diesel fuel system when you are done. See Priming the Fuel System on *page15.*

Check Fuel Hoses and Engine Coolant Hoses

Daily check the fuel system and engine coolant system hoses. If they are cracked or degraded, replace them.

Daily

After Initial 50 Hours of Operation

Perform the following maintenance after the initial 50 hours of operation.

- Replace Engine Oil and Engine Oil Filter
- Check and Adjust Cooling Fan V-Belt

Replace Engine Oil and Engine Oil Filter

⚠ WARNING

BURN HAZARD!

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

ALWAYS wear eye protection.

Failure to comply could result in death or serious injury.

⚠ WARNING

SUDDEN MOVEMENT HAZARD!

Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.

Failure to comply could result in death or serious injury.

⚠ CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap/dipstick and the surrounding area before you remove the cap.

NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

The engine oil in a new engine becomes contaminated from the initial break-in of internal parts. It is very important that the initial oil and filter change is performed as scheduled.

NOTE: The oil drain plug may be in another location if an optional oil pan is used.

Drain the engine oil as follows:

1. Make sure the engine is level.

2. Start the engine and bring it up to operating temperature.

3. Stop the engine.

4. Remove one of the oil filler caps **(Figure 5-1, (1))** to vent the engine crankcase and allow the engine oil to drain more easily.

5. Position a container under the engine to collect waste oil.

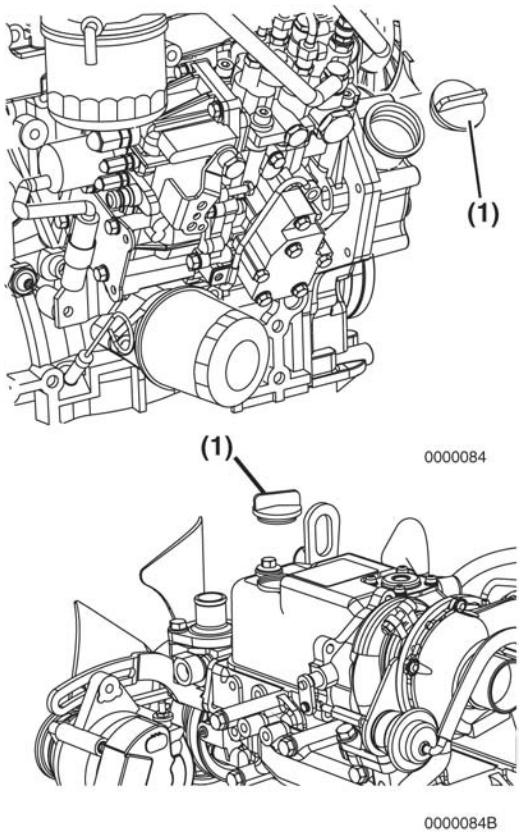


Figure 5-1

6. Remove the oil drain plug **(Figure 5-2, (1))** from the engine oil pan. Allow oil to drain.

7. After all oil has been drained from the engine, reinstall the oil drain plug (Figure 5-2, (1)) and tighten to 139.8 - 47.0 ft·lb (53.9 - 63.7 N·m; 5. 5 - 6.5 kgf·m).

8. Dispose of used oil properly.

Remove the engine oil filter as follows:

1. Turn the engine oil filter **(Figure 5-2, (2))** counterclockwise **(Figure 5-2, (3))** using a filter wrench.

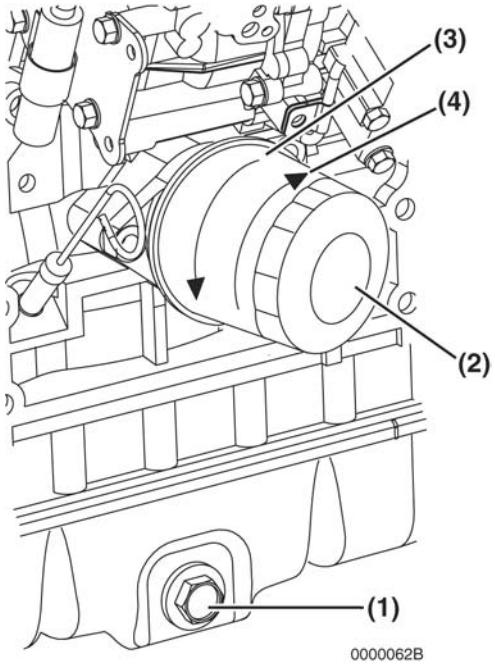


Figure 5-2

2. Clean the engine oil filter mounting face.

3. Lightly coat the gasket on the new oil filter with engine oil. Install the new engine oil filter manually by turning it clockwise **(Figure 5-2, (4))** until it contacts the mounting surface. Tighten to 14 - 17 ft·lb (19.6 - 23.5 N·m; 2.0 - 2.4 kgf·m) or one additional turn using the filter wrench.

Applicable Engine Oil Filter Part No.	
4TNV98	A408065
4TNE98	A408065

4. Add new engine oil to the engine as specified in Adding Engine Oil on page 17.

⚠ CAUTION

NEVER overfill the engine with engine oil.

ALWAYS keep the oil level between the upper and lower lines on the oil cap/dipstick.

5. Warm up the engine by running it for five minutes and check for any engine oil leaks.

6. After engine is warm, shut it off and let it sit for 10 minutes.

7. Recheck the engine oil level.

8. Add engine oil **(Figure 5-3, (5))** as needed until the level is between the upper **(Figure 5-3, (2))** and lower lines **(Figure 5-3, (3))** shown on the dipstick **(Figure 5-3, (1))**.

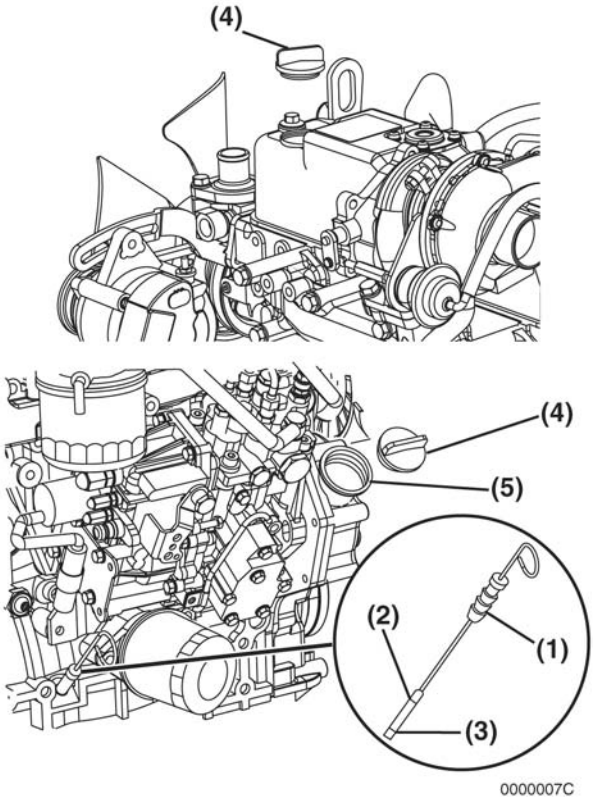


Figure 5-3

9. Reinstall the oil filler cap **(Figure 5-3, (4))**. If any engine oil is spilled, wipe it away with a clean cloth.

Check and Adjust Cooling Fan V-Belt

The V-belt will slip if it does not have the proper tension. This will prevent the alternator from generating sufficient power. Also, the engine will overheat due to the engine coolant pump pulley slipping.

Check and adjust the V-belt tension (deflection) as follows:

1. Press the V-belt down with your thumb with a force of approximately 22 ft·lb (98 N·m; 10 kgf) to check the deflection.
There are three positions to check for V-belt tension **(Figure 5-4, (A), (B)** and **(C))**. You can check the tension at whichever position is the most accessible. The proper deflection of a used V-belt at each position is:

Used V-Belt Tension		
A	**B**	**C**
3/8 - 1/2 in. (10 - 14 mm)	1/4 - 3/8 in. (7 - 10 mm)	5/16 - 1/2 in. (9 - 13 mm)

NOTE: A “Used V-Belt” refers to a V-belt which has been used on a running engine for five minutes or more.

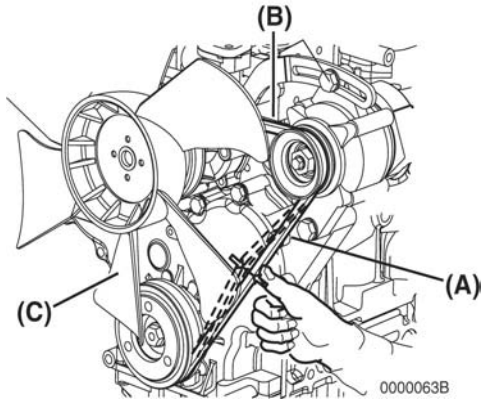


Figure 5-4

2. If necessary, adjust the V-belt tension. Loosen the adjusting bolt **(Figure 5-5, (1))** and move the alternator **(Figure 5-5, (2))** with a pry bar **(Figure 5-5, (3))** to tighten the V-belt to the desired tension. Then tighten the adjusting bolt.

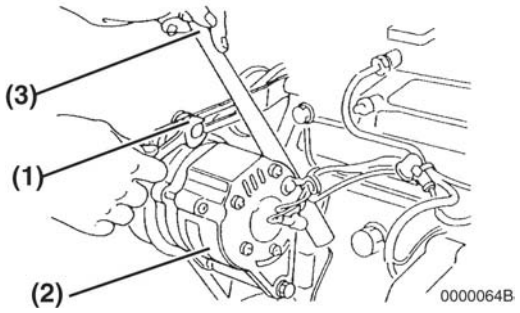


Figure 5-5

3. Tighten the V-belt to the proper tension. There must be clearance **(Figure 5-6, (1))** between the V-belt and the bottom of the pulley groove. If there is no clearance **(Figure 5-6, (2))** between the V-belt and the bottom of the pulley groove, replace the V-belt.

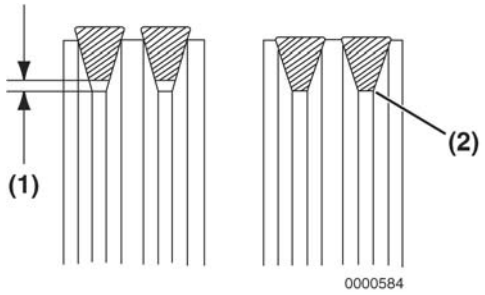


Figure 5-6

4. Check the V-belt for cracks, oil or wear. If any of these conditions exist, replace the V-belt.

5. Install the new V-belt. Refer to the table for proper tension.

New V-Belt Tension		
A	**B**	**C**
5/16 - 7/16 in. (8 - 12 mm)	3/16 - 5/16 in. (5 - 8 mm)	1/4 - 7/16 in. (7 - 11 mm)

6. After adjusting, run the engine for 5 minutes or more. Check the tension again using the specifications for a used V-belt.

Used V-Belt Tension		
A	**B**	**C**
3/8 - 1/2 in. (10 - 14 mm)	1/4 - 3/8 in. (7 - 10 mm)	5/16 - 1/2 in. (9 - 13 mm)

Every 50 Hours of Operation

After you complete the initial 50 hour maintenance procedures, perform the following procedures every 50 hours thereafter.

- Drain Fuel Filter / Water Separator
- Check Battery

Drain Fuel Filter / Water Separator

4TNV98 & 4TNE98 (For China) Engine

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.

⚠ CAUTION

If the fuel filter / water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter / water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter / water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Drain the fuel filter / water separator whenever there are contaminants, such as water, collected in the bottom of the cup. NEVER wait until the scheduled periodic maintenance if contaminants are discovered.

The cup of the separator is made from semi-transparent material. In the cup is a red colored float ring. The float ring will rise to the surface of the water to show how much needs to be drained. Also, some optional fuel filter / water separators are equipped with a sensor to detect the amount of contaminants. This sensor sends a signal to an indicator to alert the operator.

Drain the fuel filter / water separator as follows:

1. Position an approved container under the fuel filter / water separator **(Figure 5-7, (1))** to collect the contaminants.

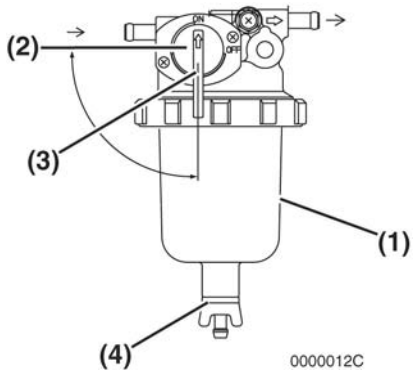


Figure 5-7

2. Close **(Figure 5-7, (2))** the fuel cock **(Figure 5-7, (3))**.

3. Loosen the drain cock **(Figure 5-7, (4))** at the bottom of the fuel filter / water separator. Drain any water collected inside.

4. Hand-tighten the drain cock.

⚠ CAUTION

If the fuel filter/water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter/water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter/water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.

5. Open the fuel cock **(Figure 5-7, (3))**.

6. Be sure to prime the diesel fuel system when you are finished. See Priming the Fuel System on page 15.

7. Check for leaks.

Check Battery

⚠ DANGER

EXPLOSION HAZARD!

NEVER check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.

If the electrolyte is frozen, slowly warm the battery before you recharge it.

Failure to comply will result in death or serious injury.

⚠ WARNING

BURN HAZARD!

Batteries contain sulfuric acid. NEVER allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. ALWAYS wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and / or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.

Failure to comply could result in death or serious injury.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

When the amount of fluid nears the lower limit **(Figure 5-8, (1))**, fill with distilled water **(Figure 5-8, (2))** so it is at the upper limit **(Figure 5-8, (3))**. If operation continues with insufficient battery fluid, the battery life is shortened, and the battery may overheat and explode. During the summer, check the fluid level more often than specified.

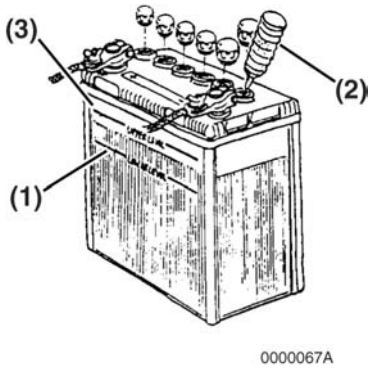


Figure 5-8

If the engine cranking speed is so slow that the engine does not start, recharge the battery.

If the engine still will not start after charging, have your authorized Yanmar industrial engine dealer or distributor check the battery and the engine's starting system.

If operating the machine where the ambient temperature could drop to 5°F (-15°C) or less, remove the battery from the machine at the end of the day. Store the battery in a warm place until the next use. This will help start the engine easily at low ambient temperatures.

Every 250 Hours of Operation

Perform the following maintenance every 250 hours of operation.

- Drain Fuel Tank
- Check and Clean Radiator Fins
- Check and Adjust Cooling Fan V-Belt
- Check and Adjust the Governor Lever and Engine Speed Control
- Clean Air Cleaner Element

Drain Fuel Tank

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Note that a typical fuel tank is illustrated.

1. Position an approved container under the diesel fuel tank **(Figure 5-9, (1))** to collect the contaminates.

2. Remove the fuel cap **(Figure 5-9, (3)).**

3. Remove the drain plug **(Figure 5-9, (2))** of the fuel tank to drain the contaminates (water, dirt, etc.) from the bottom of the tank.

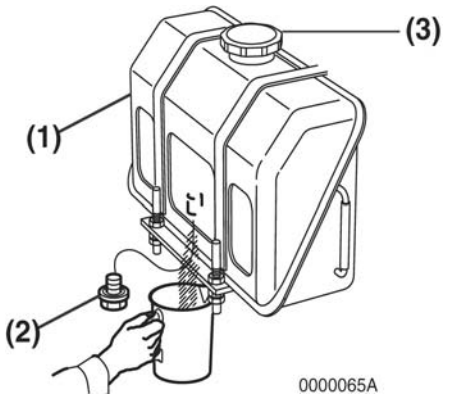


Figure 5-9

4. Drain the tank until clean diesel fuel with no water and dirt flows out. Reinstall and tighten the drain plug firmly.

5. Reinstall the fuel cap.

6. Check for leaks.

Check and Clean Radiator Fins

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

Dirt and dust adhering to the radiator fins reduce the cooling performance, causing overheating. Make it a rule to check the radiator fins daily and clean as needed.

Note that a typical radiator is shown in **Figure 5-10** for illustrative purposes only.

- Blow off dirt and dust from fins and radiator with 28 psi (0.19 MPa; 2 kgf/cm²) or less of compressed air **(Figure 5-10, (1))**. Be careful not to damage the fins with the compressed air.
- If there is a large amount of contamination on the fins, apply detergent, thoroughly clean and rinse with tap water.

⚠ CAUTION

NEVER use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19 686 mmAq) or a wire brush to clean the radiator fins. Radiator fins damage easily.

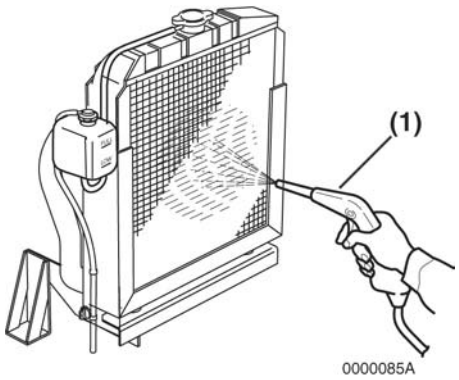


Figure 5-10

Check and Adjust Cooling Fan V-Belt

Check and adjust the cooling fan V-belt every 250 hours of operation after the initial 50 hour V-belt maintenance. See Check and Adjust Cooling Fan V-Belt on page 47.

Check and Adjust the Governor Lever and Engine Speed Control

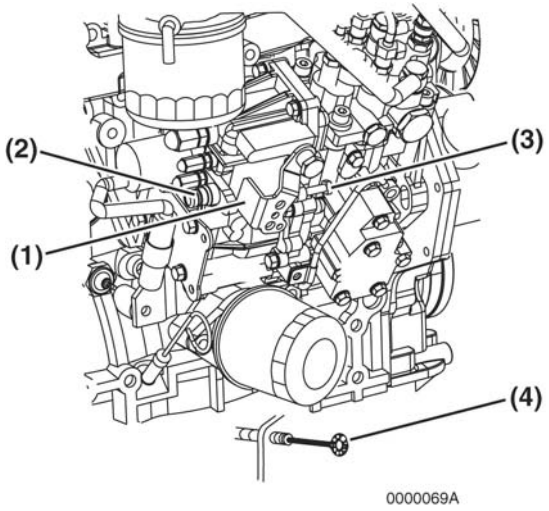
The governor lever and engine speed control (throttle lever, pedal, etc.) of the machine are connected together by a throttle cable or rod. If the cable becomes stretched, or the connections loosen, the governor lever may not respond to change of engine speed control position. This may make operation of the machine unsafe. Check the cable periodically and adjust if necessary.

NEVER force the throttle cable or pedal to move. This may deform the governor lever or stretch the cable and cause irregular operation of the engine speed control.

Checking and adjusting the governor lever:

1. Check that the governor lever **(Figure 5-11, (1))** makes uniform contact with the high idle **(Figure 5-11, (2))** and low idle **(Figure 5-11, (3))** speed limit screws when the engine speed control is in the high idle speed or low idle speed position.

4TNV98 ENGINE



4TNE98 ENGINE

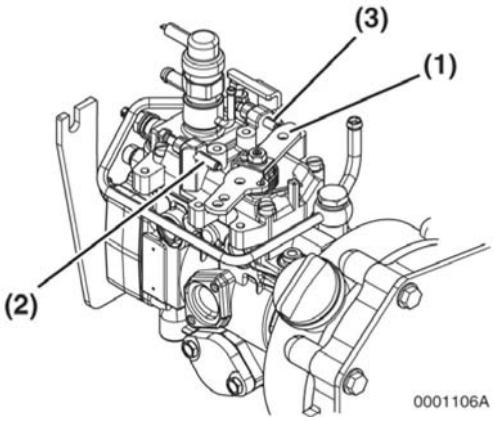


Figure 5-11

2. If the governor lever does not make contact with the high idle or low idle speed limit screw, adjust the throttle cable.

3. In some engine speed control applications, loosen the throttle cable lock nut **(Figure 5-11, (4))** and adjust the cable so the governor lever makes proper contact with the high / low idle speed limit screw.

⚠ CAUTION

NEVER attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the machine and shorten its life. If the idle speed limit screws require adjustment, see your authorized Yanmar industrial engine dealer or distributor.

Clean Air Cleaner Element

Note that a typical air cleaner is shown in **Figure 5-12** and **Figure 5-13** for illustrative purposes only.

The engine performance is adversely affected when the air cleaner element is clogged with dust.
Be sure to clean the air filter element periodically.

1. Unlatch and remove the air cleaner cover **(Figure 5-12, (1)).**

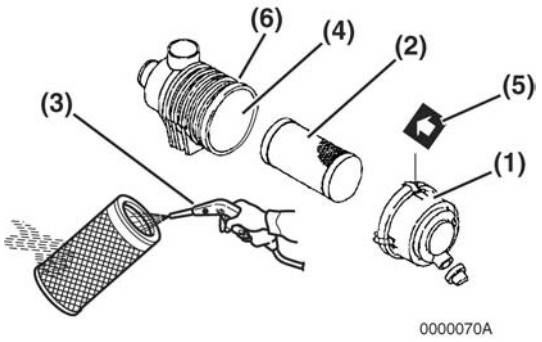


Figure 5-12

2. Remove the element **(Figure 5-12, (2))** (outer element if equipped with two elements).

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

3. Blow air **(Figure 5-12, (3))** through the element from the inside out using 42-71 psi (0.29-0.49MPa; 3.0-5.0 kgf/cm²) compressed air to remove the particulates. Use the lowest possible air pressure to remove the dust without damaging the element.
4. If the air cleaner is equipped with a double element, only remove and replace the inner element **(Figure 5-13, (1))** if the engine lacks power or the dust indicator actuates (if equipped).

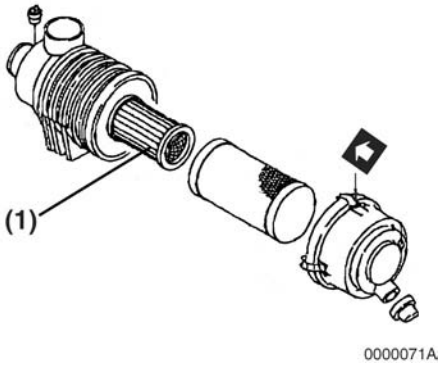


Figure 5-13

5. The inner element should not be removed when cleaning or replacing the outer element. The inner element is used to prevent dust from entering the engine while servicing the outer element.

6. Replace the element with a new one if the element is damaged, excessively dirty or oily.

7. Clean inside of the air cleaner cover.

8. Install the element into the air cleaner case **(Figure 5-12, (4))**.

9. Reinstall the air cleaner cover making sure you match the arrow **(Figure 5-12, (5))** on the cover with the arrow on the case **(Figure 5-12, (6))**.

10. Latch the air cleaner cover to the case.

⚠ CAUTION

When the engine is operated in dusty conditions, clean the air cleaner element more frequently.

NEVER operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.

Every 500 Hours of Operation

Perform the following maintenance every 500 hours of operation.

- Replace Engine Oil and Engine Oil Filter
- Replace Air Cleaner Element
- Replace Fuel Filter
- Clean Fuel Filter / Water Separator

Replace Engine Oil and Engine Oil Filter

⚠ CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap/dipstick and the surrounding area before you remove the cap.

NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Change the engine oil every 250 hours of operation after the initial change at 50 hours. Replace the engine oil filter at the same time. See Replace Engine Oil and Engine Oil Filter on page 45.

Replace Air Cleaner Element

⚠ CAUTION

The maximum air intake restriction, in terms of differential pressure measurement, must not exceed 0.90 psi (6.23 kPa; 635 mmAq). Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

Replace the air cleaner element **(Figure 5-12, (2))** every 500 hours even if it is not damaged or dirty.

When replacing the element, clean the inside of the air cleaner case **(Figure 5-12, (4))**.

If the air cleaner is equipped with a double element, only remove and replace the inner element **(Figure 5-13, (1))** if the engine lacks power or the dust indicator actuates (if equipped). This is in addition to replacing the outer element.

Replace Fuel Filter

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.

⚠ CAUTION

For maximum engine life, Yanmar recommends that when shutting the engine down, you allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

4TNV98 & 4TNE98 (for D25G) Only

Replace the fuel filter at specified intervals to prevent contaminants from adversely affecting the diesel fuel flow.

1. Stop the engine and allow it to cool.

2. Close the fuel cock of the fuel filter / water separator.

3. Remove the fuel filter with a filter wrench, turning it to the left (Figure 5-14, (1)). When removing the fuel filter, carefully hold it to prevent the fuel from spilling. Wipe up all spilled fuel.

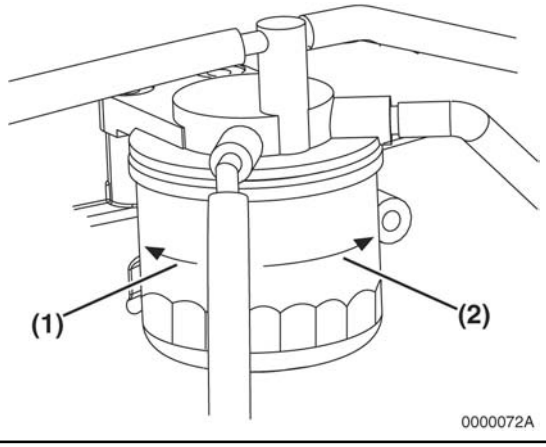


Figure 5-14

4. Clean the filter mounting surface and apply a small amount of diesel fuel to the gasket of the new fuel filter.

5. Install the new fuel filter. Turn to the right **(Figure 5-14, (2))** and hand-tighten it only until it comes in contact with the mounting surface. Tighten to 14-17 ft·lb (19.6-23.5 N·m; 2.0-2.4kgf·m) or one additional turn using the filter wrench.

Applicable Fuel Filter Part No.	
4TNV98	A408064

6. Open the fuel cock of the fuel filter / water separator.

7. Prime the fuel system. See Priming the Fuel System on page 15.

8. Check for leaks.

4TNE98 (for D25S-5) Only

Replace the fuel filter at specified intervals to prevent contaminants from adversely affecting the diesel fuel flow.

1. Stop the engine and allow it to cool.

2. Close all fuel cocks in fuel line.

3. Disconnect the fuel filter sensor connector **(Figure 5-14a, (1)).**

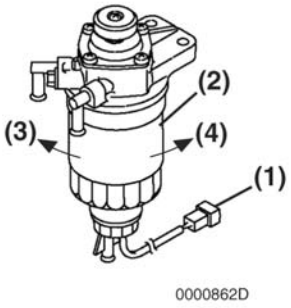


Figure 5-14a

4. Place an approved container under fuel filter.

5. Carefully open the drain plug **(Figure 5-15a, (1))** to drain fuel from the fuel filter.

6. Remove the fuel filter **(Figure 5-14a, (2))** by turning it to the left **(Figure 5-14a, (3))**. Wipe up all spilled fuel.

7. Remove the drain plug **(Figure 5-15a, (1))** from the fuel filter **(Figure 5-15a, (2))** by turning it to the left **(Figure 5-15a, (3)).**

8. Check the condition of the drain plug O-ring **(Figure 5-15a, (4)).** Replace the O-ring if damaged.

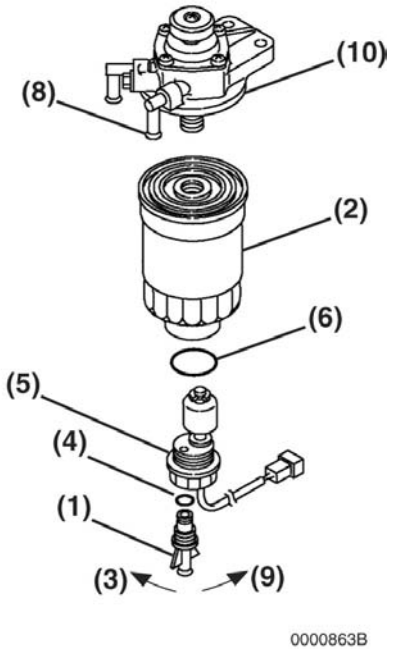


Figure 5-15

9. Set the drain plug aside for reinstallation.

10. Remove the fuel filter sensor assembly **(Figure 5-15, (5))** by turning it to the left **(Figure 5-15, (3))**.

11. Carefully remove the in-line fuel filter **(Figure 5-15, (7))** from the output nipple **(Figure 5-15, (8))** that goes to the fuel injection pump.

12. Dispose of the fuel, fuel filters and O-ring (if replaced) properly. Follow the guidelines of the EPA or other government agency.

13. Carefully install the output nipple **(Figure 5-15, (8))**.

14. Carefully install the fuel filter sensor assembly **(Figure 5-15, (5))** in the new fuel filter using the new O-ring supplied with the fuel filter **(Figure 5-15, (2))** by turning the fuel filter sensor assembly to the right **(Figure 5-15, (9)).**

15. Install the drain plug **(Figure 5-15, (1))** on the new fuel filter **(Figure 5-15, (3))** by turning the drain plug to the right **(Figure 5-15, (8))**. Hand tighten only.

16. Clean the fuel filter mounting surface **(Figure 5-15, (10))** and apply a small amount of diesel fuel to the gasket of the new filter.

17. Install the new fuel filter **(Figure 5-14, (2))** by turning it to the right **(Figure 5-14, (4))** until it contacts the mounting surface. Tighten one additional turn.

18. Open all fuel cocks in the fuel line.

19. Reconnect the fuel filter sensor connector **(Figure 5-14, (1))**.

20. Prime the fuel system. See Priming the Fuel System on page 15.

21. Check for fuel leaks.

Applicable Fuel Filter Part No. (Figure 5-14, (2))	
4TNE98	A409559

Clean Fuel Filter / Water Separator

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

NEVER use diesel fuel as a cleaning agent.

Failure to comply will result in death or serious injury.

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Periodically clean the fuel filter / water separator element and inside cup.

1. Position an approved container under the cup **(Figure5-15, (1))** of the fuel filter / water separator to collect the contaminants.

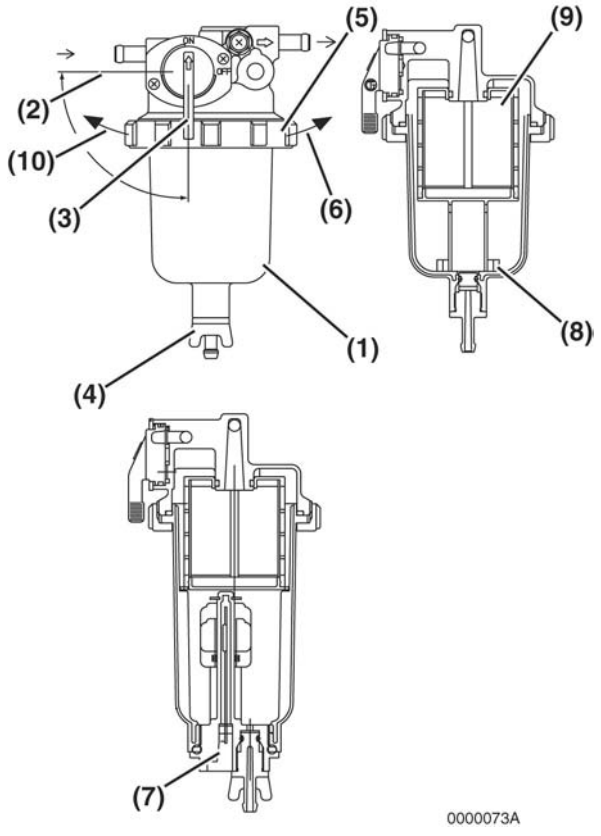


Figure 5-15

2. Close **(Figure 5-15, (2))** the fuel cock **(Figure 5-15, (3))**.

3. Loosen the drain cock **(Figure 5-15, (4))** and drain the contaminants. See Drain Fuel Filter/Water Separator on page 41.

4. Turn the retaining ring **(Figure 5-15, (5))** to the left **(Figure 5-15, (10))** and remove the cup **(Figure 5-15, (6))**. If equipped, disconnect the sensor wire **(Figure 5-15, (7))** from the cup before removing the cup.

5. Carefully hold the cup to prevent fuel from spilling. If you spill any fuel, clean up the spill completely.

6. Remove the float ring **(Figure 5-15, (8))** from the cup. Pour the contaminants into the container and dispose of it properly.

7. Clean the element **(Figure 5-15, (9))** and inside cup. Replace the element if it is damaged.

Applicable Fuel Filter Part No.	
4TNV98	A408054
4TNE98 (for D30G)	A408054

8. Install the element and O-ring in the bracket.

9. Position the float ring in the cup.

10. Check the condition of the cup O-ring. Replace if necessary.

11. Install the cup to the bracket by tightening the retaining ring to the right **(Figure 5-15, (6))** to a torque of 11-15 ft·lb (15-20 N·m; 1.5-2.0kgf·m).

12. Close the drain cock. Reconnect the sensor wire if equipped.

13. Open the fuel cock **(Figure 5-15, (3))**.

14. Prime the fuel system. See Priming the Fuel System on page 15.

15. Check for leaks.

Every 1000 Hours of Operation

Perform the following maintenance every 1000 hours of operation.

- Drain, Flush and Refill Cooling System With New Coolant
- Adjust Intake/Exhaust Valve Clearance

Drain, Flush and Refill Cooling System With New Coolant

⚠ DANGER

SCALD HAZARD!

NEVER remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

ALWAYS check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.

⚠ WARNING

BURN HAZARD!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.

⚠ CAUTION

COOLANT HAZARD!

Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Engine coolant contaminated with rust or scale reduces the cooling effect. Even when extended life engine coolant is properly mixed, the engine coolant gets contaminated as its ingredients deteriorate. Drain, flush and refill the cooling system with new coolant every 1000 hours or once a year, whichever comes first.

1. Allow engine and coolant to cool.

2. Remove the radiator cap **(Figure 5-16, (1)).**

3. Remove the drain plug or open the drain cock **(Figure 5-16, (2))** at the lower portion of the radiator and drain the engine coolant.

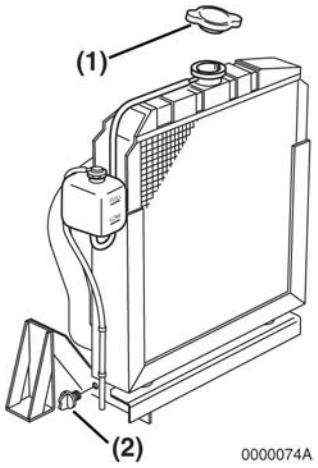


Figure 5-16

4. Drain the coolant from the engine block.

- On models not equipped with an oil cooler, remove the coolant drain plug **(Figure 5-17, (1))** from the engine block.

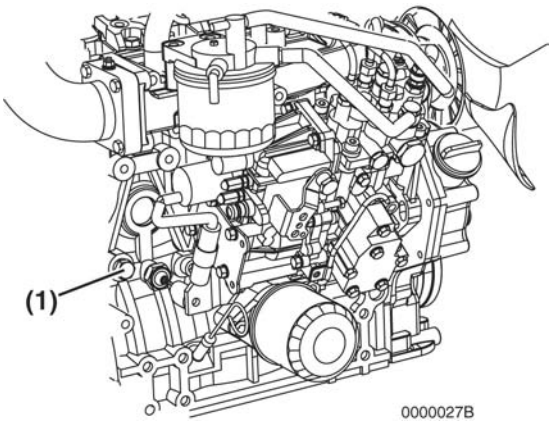


Figure 5-17

5. After draining the engine coolant, flush the radiator and engine block to remove any rust, scale and contaminants. Then reinstall and tighten the drain plug or close the drain cock in the radiator. Reinstall and tighten the cylinder block drain plug or reconnect the coolant hose at the oil cooler.

6. Fill radiator and engine with engine coolant. See Filling Radiator with Engine Coolant on page 19.

Adjust Intake / Exhaust Valve Clearance

Proper adjustment is necessary to maintain the correct timing for opening and closing the valves. Improper adjustment will cause the engine to run noisily, resulting in poor engine performance and engine damage. See Intake/Exhaust Valve and Guide on page 67.

Every 1500 Hours of Operation

Perform the following maintenance every 1500 hours of operation.

- Inspect, Clean and Test Fuel Injectors
- Inspect Crankcase Breather System

Inspect, Clean and Test Fuel Injectors

⚠ WARNING

HIGH-PRESSURE HAZARD!

Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.

NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard. Have your authorized Yanmar industrial engine dealer or distributor repair the damage.

Failure to comply could result in death or serious injury.

Proper operation of the fuel injectors is required to obtain the optimum injection pattern for full engine performance. The EPA / ARB requires that the fuel injectors are inspected, cleaned and tested every 1500 hours. See Testing of Fuel Injectors on page 164.

This procedure is considered normal maintenance and is performed at the owner's expense. This procedure is not covered by the Yanmar Limited Warranty.

Inspect Crankcase Breather System

Proper operation of the crankcase breather system is required to maintain the emission requirements of the engine. The EPA / ARB requires that the crankcase breather system is inspected every 1500 hours.

There are three different crankcase breather systems used on the TNV engines. Only the non-turbo TNV engines crankcase breather system requires periodic maintenance.

The non-turbo TNV engines use a crankcase breather system that has a spring-backed diaphragm **(Figure 5-19, (1))** in the valve cover **(Figure 5-19, (2))**. When the crankcase pressure reaches a predetermined value, the diaphragm opens a passage that allows crankcase fumes to be routed to the intake manifold.

To inspect the diaphragm and spring **(Figure 5-19, (3))**:

1. Remove the bolts retaining the diaphragm cover **(Figure 5-19, (4)).**

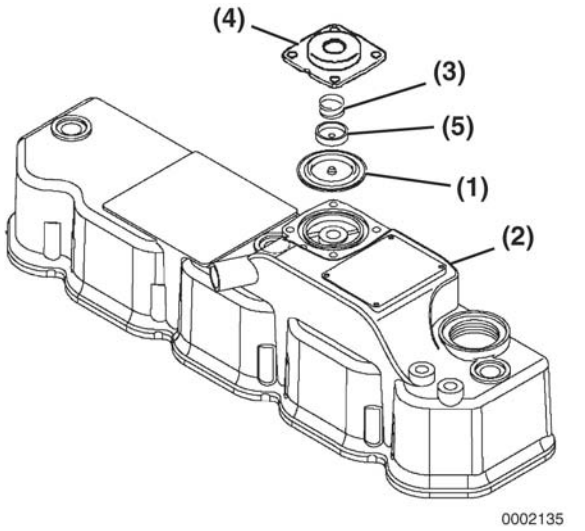


Figure 5-19

2. Remove the diaphragm cover, spring, diaphragm plate **(Figure 5-19, (5))** and diaphragm.

3. Inspect the diaphragm for tears. Inspect the spring for distortion. Replace components if necessary.

4. Reinstall the diaphragm, diaphragm plate, spring and diaphragm cover. Tighten the diaphragm bolts to specified torque.

Failure of the diaphragm and / or spring will cause the loss of pressure control and allow an excessive amount of crankcase fumes to be routed to the intake manifold. This could result in excessive deposits in the intake system, high engine exhaust smoke levels, excessive engine oil consumption, and / or engine run-on due to the burning of the engine oil.

Every 2000 Hours of Operation

Perform the following maintenance every 2000 hours of operation.

- Check and Replace Fuel Hoses and Engine Coolant Hoses
- Lap the Intake and Exhaust Valves

Check and Replace Fuel Hoses and Engine Coolant Hoses

⚠ CAUTION

ALWAYS be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Regularly check the fuel system and engine coolant system hoses. If they are cracked or degraded, replace them. Replace the hoses at least every two years.

Lap the Intake and Exhaust Valves

Adjustment is necessary to maintain proper contact of the valves and seats. See Inspection of Intake and Exhaust Valves on page 98.

Section 3. ENGINE

Before You Begin Servicing

⚠ WARNING

To prevent possible eye injury, always wear SAFETY GLASSES while servicing the engine.

⚠ WARNING

ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it. NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.

Failure to comply could result in death or serious injury..

⚠ WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

⚠ CAUTION

Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.

CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap/dipstick and the surrounding area before you remove the cap.

NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and/or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

CAUTION

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.

CAUTION

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.

CAUTION

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

Introduction

This section of the Service Manual describes servicing of the engine.

Cylinder Head Specifications

Adjustment Specifications

Model	Valve Clearance	Valve Bridge Clearance (4-Valve Head Only)
4TNV98	0.006 - 0.010 in. (0.15 - 0.25 mm)	0
4TNE98	0.006 - 0.010 in. (0.15 - 0.25 mm)	-

Cylinder Head

4TNV98 Engine

Inspection Item			Standard	Limit	Reference Page
Combustion Surface Distortion (Flatness)			0.0020 in. (0.05 mm) or less	0.0059 in. (0.15 mm)	See Valve Recession on Page 95 and 98.
Valve Recession	4TNV98 (4-Valve Head)	Intake Exhaust	0.0142 - 0.0220 in. (0.36 - 0.56 mm) 0.0138 - 0.0217 in. (0.35 - 0.55 mm)	0.0315 in. (0.8 mm) 0.0315 in. (0.8 mm)	
Valve Seat (4-Valve)	Seat Angle	Intake	120°	-	See Valve Face and Valve Seat on Page 96 and 99.
		Exhaust	90°	-	
	Seat Correction Angle		40°, 150°	-	

4TNE98 Engine

Inspection Item		Standard	Limit	Reference Page
Combustion Surface Distortion (Flatness)		0.0020 in. (0.05 mm) or less	0.0059 in. (0.15 mm)	See Inspection of Cylinder Head on page 94.
Valve Sink	Intake	0.020 - 0.028 in. (0.5 - 0.7 mm)	0.039 in. (1.0 mm)	See Inspection of Intake and Exhaust Valves on page 95.
	Exhaust	0.024 - 0.032 in. (0.6 - 0.8 mm)	0.043 in. (1.1 mm)	
Valve Seat Angle	Intake	120°	-	
	Exhaust	90°	-	

Intake / Exhaust Valve and Guide Cont

4TNV98 Engine

Inspection Item			Standard	Limit	Reference Page
4TNV98 (4-Valve Head)	Intake	Guide Inside Diameter	0.2756 - 0.2762 in. (7.000 - 7.015 mm)	0.2787 in. (7.08 mm)	See Inspection of Valve Guides on page 94.
		Valve Stem Outside Diameter	0.2734 - 0.2740 in. (6.945 - 6.960 mm)	0.2717 in. (6.90 mm)	
		Oil Clearance	0.0016 - 0.0028 in. (0.040 - 0.070 mm)	0.0067 in. (0.17 mm)	
	Exhaust	Guide Inside Diameter	0.2756 - 0.2762 in. (7.000 - 7.015 mm)	0.2787 in. (7.08 mm)	
		Valve Stem Outside Diameter	0.2732 - 0.2738 in. (6.940 - 6.955 mm)	0.2717 in. (6.90 mm)	
		Valve Stem Bend	0.0018 - 0.0030 in. (0.045 - 0.075 mm)	0.0067 in. (0.17 mm)	
Valve Guide Projection From Cylinder Head			0.3819 - 0.3937 in. (9.70 - 10.00 mm)	-	See Reassembly of Valve Guides on page 97 and 103.
Valve Guide Installation Method			Cold-fitted	-	
Valve Stem Seal Projection From Cylinder Head			0.460 - 0.472 in. (11.7 - 12.0 mm)	-	See Reassembly of Intake and Exhaust Valves on page 98.

4TNE98 Engine

Inspection Item		Standard	Limit	Reference Page
Intake Valve	Guide Inside Diameter	0.3156 - 0.3161 in. (8.015 – 8.030 mm)	0.3189 in. (8.10 mm)	See Inspection of Intake and Exhaust Valves on page 95.
	Valve Stem Outside Diameter	0.3136 - 0.3142 in. (7.965 – 7.980 mm)	0.3110 in. (7.90 mm)	
	Oil Clearance	0.0014 - 0.0026 in. (0.035 - 0.065 mm)	0.0071 in. (0.18 mm)	
Exhaust Valve	Guide Inside Diameter	0.3156 - 0.3161 in. (8.015 – 8.030 mm)	0.3189 in. (8.10 mm)	
	Valve Stem Outside Diameter	0.3136 - 0.3138 in. (7.965 – 7.970 mm)	0.3110 in. (7.90 mm)	
	Oil Clearance	0.0018 - 0.0030 in. (0.045 - 0.075 mm)	0.0071 in. (0.18 mm)	
Valve Guide Projection From Cylinder Head		0.58 - 0.60 in. (14.7 – 15.0 mm)	-	See Assembly of Valve Guides on page 98.
Valve Stem Seal Projection From Cylinder Head		0.66 - 0.70 in. (16.7 – 17.0 mm)	-	See Assembly of Valve Guides on page 98.

Push Rod

Inspection Item	Standard	Limit	Reference Page
Page Push Rod Bend	Less than 0.0012 in. (0.03 mm)	0.0012 in. (0.03 mm)	See Push Rod Bend on page 93.

Rocker Arm and Shaft

Inspection Item	Standard	Limit	Reference Page
Arm Shaft Hole Diameter	0.7283 - 0.7291 in. (18.500 - 18.520 mm)	0.7311 in. (18.57 mm)	See Inspection of Rocker Arm Assembly on page 93 and 94.
Shaft Outside Diameter	0.7272 - 0.7280 in. (18.470 - 18.490 mm)	0.7260 in. (18.44 mm)	
Oil Clearance	0.0004 - 0.0020 in. (0.010 - 0.050 mm)	0.0051 in. (0.13 mm)	

Valve Spring

Inspection Item	Model	Standard	Limit	Reference Page
Free Length	4TNV98 (4-Valve Head)	1.5630 in. (39.7 mm)	1.5433 in. (39.2 mm)	See Inspection of Valve Springs on page 97 and 101.
	4TNE98	1.87 in. (47.5 mm)	-	
Squareness	4TNV98 (4-Valve Head)	-	0.0551 in. (1.4 mm)	
	4TNE98	-	0.05 in. (1.2 mm)	

Camshaft and Timing Gear Train Specifications

Camshaft

Inspection Item		Standard	Limit	Reference Page
End Play		0.0020 - 0.0079 in. (0.05 - 0.20 mm)	0.0118 in. (0.030 mm)	See Removal of Camshaft on page 114.
Bend (1/2 the dial gauge reading)		0 - 0.0008 in. (0 - 0.02 mm)	0.0020 in. (0.05 mm)	See Inspection of Camshaft on page 125.
Cam Lobe Height	4TNV98	1.7087 - 1.7165 in. (43.400 - 43.600 mm)	1.6988 in. (43.150 mm)	
	4TNE98	1.6707 - 1.6758 in. (42.435– 42.565 mm)	1.6608 in. (42.185 mm)	
Shaft Outside Diameter / Bearing Inside Diameter				

(Camshaft Cont.)

Inspection Item		Standard	Limit	Reference Page
Gear End	Bushing Inside Diameter	1.9681 - 1.9707 in. (49.990 - 50.055 mm)	1.9736 in. (50.130 mm)	See Inspection of Camshaft on page 125.
	Camshaft Outside Diameter	1.9655 - 1.9665 in. (49.925 - 49.950 mm)	1.9642 in. (49.890 mm)	
	Oil Clearance	0.0016 - 0.0051 in. (0.040 - 0.130 mm)	0.0094 in. (0.240 mm)	
Intermediate	Bushing Inside Diameter	1.9685 - 1.9695 in. (50.000 - 50.025 mm)	1.9724 in. (50.100 mm)	
	Camshaft Outside Diameter	1.9650 - 1.9659 in. (49.910 - 49.935 mm)	1.9636 in. (49.875 mm)	
	Oil Clearance	0.0026 - 0.0045 in. (0.065 - 0.115 mm)	0.0089 in. (0.225 mm)	
Flywheel End	Bushing Inside Diameter	1.9685 - 1.9695 in. (50.000 - 50.025 mm)	1.9724 in. (50.100 mm)	
	Camshaft Outside Diameter	1.9655 - 1.9665 in. (49.925 - 49.950 mm)	1.9642 in. (49.890 mm)	
	Oil Clearance	0.0020 - 0.0039 in. (0.050 - 0.100 mm)	0.0083 in. (0.210 mm)	

Idler Gear Shaft and Bushing

Inspection Item	Standard	Limit	Reference Page
Shaft Outside Diameter	1.8091 - 1.8100 in. (45.950 - 45.975 mm)	1.8071 in. (45.900 mm)	See Inspection of Idler Gear and Shaft on page 126.
Bushing Inside Diameter	1.8110 - 4.8120 in. (46.000 - 46.025 mm)	1.8140 in. (46.075 mm)	
Oil Clearance	0.0010 - 0.0030 in. (0.025 - 0.075 mm)	0.0069 in. (0.175 mm)	

Timing Gear Backlash

Inspection Item	Standard	Limit	Reference Page
Crank Gear, Cam Gear, Idler Gear, Fuel Injection Pump Gear and PTO Gear	0.0031 - 0.0055 in. (0.08 - 0.14 mm)	0.0063 in. (0.16 mm)	See Checking Timing Gear Backlash on page 112.
Lubricating Oil Pump Gear	0.0035 - 0.0059 in. (0.09 - 0.15 mm)	0.0067 in. (0.17 mm)	

Crankshaft and Piston Specifications

Crankshaft

NOTE : Check appropriate parts catalog for various sizes of replacement main bearing inserts.

Inspection Item		Standard	Limit	Reference Page
Bend (1/2 the dial gauge reading)		-	0.0008 in. (0.02 mm)	See Inspection of Crankshaft on Page 124.
Connecting Rod Journals	Journal Outside Diameter	2.2816 - 2.2820 in. (57.952 - 57.962 mm)	2.2796 in. (57.902 mm)	
	Bearing Inside Diameter	2.2835 - 2.2845 in. (58.000 - 58.026 mm)	-	
	Bearing Insert Thickness	0.0587 - 0.0591 in. (1.492 - 1.500 mm)	-	
	Oil Clearance	0.0015 - 0.0029 in. (0.038 - 0.074 mm)	0.0059 in. (0.150 mm)	
Main Bearing Journal	Journal Outside Diameter	2.5572 - 2.5576 in. (64.952 - 64.962 mm)	2.5552 in. (64.902 mm)	See Inspection of Crankshaft on page 124.
	Bearing Inside Diameter	2.5590 - 2.5598 in. (65.000 - 65.020 mm)	-	
	Bearing Insert Thickness	0.0785 - 0.0791 in. (1.995 - 2.010 mm)	-	
	Oil Clearance	0.0015 - 0.0027 in. (0.038 - 0.068 mm)	0.0059 in. (0.150 mm)	

Thrust Bearing

Inspection Item		Standard	Limit	Reference Page
Crankshaft End Play	4TNV98	0.0051 - 0.0091 in. (0.13 - 0.23 mm)	0.0110 in. (0.28 mm)	See Removal of Crankshaft on Page 118.
	4TNE98	0.0043 - 0.0083 in. (0.11 - 0.21 mm)	0.0110 in. (0.28 mm)	

Piston

Inspection Item		Standard	Limit	Reference Page
Piston Outside Diameter (Measure at 90° to the Piston Pin.)		3.8555 - 3.8567 in. (97.930 - 97.960 mm)	3.8541 in. (97.895 mm)	See Inspection of Pistons, Piston Rings and Wrist Pin on page 122.
Piston Diameter Measure Location(Upward From the Bottom of the Piston.)		0.8661 in. (22 mm)	-	
Piston Pin	Hole Inside Diameter	1.1811 - 1.1815 in. (30.000 - 30.009 mm)	1.1826 in. (30.039 mm)	See Inspection of Pistons, Piston Rings and Wrist Pin on page 122.
	Pin Outside Diameter	1.1807 - 1.1811 in. (29.989 - 30.000 mm)	1.1795 in. (29.959 mm)	
	Oil Clearance	0.0000 - 0.0008 in. (0.000 - 0.020 mm)	0.0031 in. (0.080 mm)	

Piston Ring

Model	Inspection Item		Standard	Limit	Reference Page
4TNV98	Top Ring	Ring Groove Width	0.0803 - 0.0811 in. (2.040 - 2.060 mm)	-	See Inspection of Pistons, Piston Rings and Wrist Pin on page 122.
		Ring Width	0.0764 - 0.0772 in. (1.940 - 1.960 mm)	0.0756 in. (1.920 mm)	
		Side Clearance	0.0031 - 0.0047 in. (0.080 - 0.120 mm)	-	
		End Gap	0.0098 - 0.0177 in. (0.250 - 0.450 mm)	0.0213 in. (0.540 mm)	
	Second Ring	Ring Groove Width	0.0819 - 0.0825 in. (2.080 - 2.095 mm)	0.0864 in. (2.195 mm)	
		Ring Width	0.0776 - 0.0783 in. (1.970 - 1.990 mm)	0.0768 in. (1.950 mm)	
		Side Clearance	0.0035 - 0.0049 in. (0.090 - 0.125 mm)	0.0096 in. (0.245 mm)	
		End Gap	0.0177 - 0.0256 in. (0.450 - 0.650 mm)	0.0287 in. (0.730 mm)	
	Oil Ring	Ring Groove Width	0.1187 - 0.1193 in. (3.015 - 3.030 mm)	0.1232 in. (3.130 mm)	
		Ring Width	0.1169 - 0.1177 in. (2.970 - 2.990 mm)	0.1161 in. (2.950 mm)	
		Side Clearance	0.0010 - 0.0024 in. (0.025 - 0.060 mm)	0.0071 in. (0.180 mm)	
		End Gap	0.0098 - 0.0177 in. (0.250 - 0.450 mm)	0.0217 in. (0.550 mm)	

Connecting Rod

Connecting Rod Small End

Inspection Item	Standard	Limit	Reference Page
Wrist Pin Bushing Inside Diameter	1.1821 - 1.1826 in. (30.025 - 30.038 mm)	1.1838 in. (30.068 mm)	See Inspection of Connecting Rod on page 124.
Wrist Pin Outside Diameter	1.1806 - 1.1811 in. (29.987 - 30.000 mm)	1.1795 in. (29.959 mm)	
Oil Clearance	0.0010 - 0.0020 in. (0.025 - 0.51 mm)	0.0043 in. (0.109 mm)	

Connecting Rod Big End

Inspection Item		Standard	Limit	Reference Page
Side Clearance (Thrust Clearance)	4TNV98	0.0079 - 0.0157 in. (0.20 - 0.40 mm)	-	See Inspection of Connecting Rod on page 124.
	4TNE98	0.0051 - 0.0091 in.	-	

See Special Torque Chart on page 69 for other specifications.

Tappet

Inspection Item	Standard	Limit	Reference Page
Tappet Bore (Block) Inside Diameter	0.4724 - 0.4731 in. (12.000 - 12.018 mm)	0.4739 in. (12.038 mm)	See Inspection of Tappets on page 124.
Tappet Stem Outside Diameter	0.4715 - 0.4720 in. (11.975 - 11.990 mm)	0.4707 in. (11.955 mm)	
Oil Clearance	0.0004 - 0.0017 in. (0.010 - 0.043 mm)	0.0033 in. (0.083 mm)	

Cylinder Block Specifications

Cylinder Block

Inspection Item		Standard	Limit	Reference Page
Cylinder Inside Diameter		3.8583 - 3.8594 in. (98.000 - 98.030 mm)	3.8634 in. (98.130 mm)	See Inspection of Cylinder Block on page 121.
Cylinder Bore	Roundness	0.0004 in. (0.01 mm) or less	0.0012 in. (0.03 mm)	
	Taper			

Special Torque Chart

Torque for Bolts and Nuts

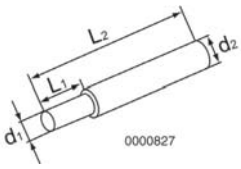
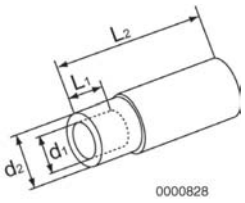
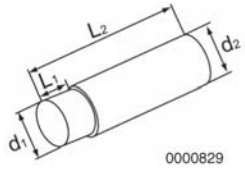
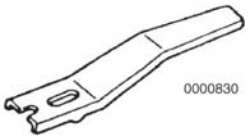
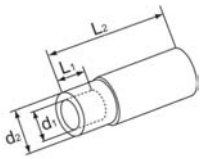
Component	Thread Diameter and Pitch	Torque	Lubricating Oil Application (Thread Portion and Seat Surface)
Cylinder Head Bolt	M11 x 1.25 mm	76 - 83 ft·lb (103.1 - 112.9 N·m; 10.5 - 11.5 kgf·m)	Applied
Connecting Rod Bolt	M10 x 1.0 mm	40 - 43 ft·lb (53.9 - 58.8 N·m; 5.5 - 6.0 kgf·m)	Applied
Flywheel Bolt	M14 x 1.5 mm	137 - 152 ft·lb (186.2 - 205.8 N·m; 19 - 21 kgf·m)	Applied

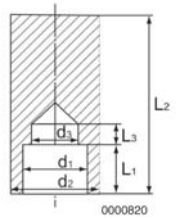
(Torque for Bolts and Nuts Cont.)

Component		Thread Diameter and Pitch	Torque	Lubricating Oil Application (Thread Portion and Seat Surface)
Main Bearing Cap Bolt		M11 x 1.25 mm	80 - 87 ft·lb (108.1 - 117.9 N·m; 11.0 - 12.0 kgf·m)	Applied
Crankshaft Pulley Bolt		M14 x 1.5 mm	80 - 94 ft·lb (107.9 - 127.5 N·m; 11.0 - 13.0 kgf·m)	Applied
Fuel Injector Bolt	4TNV98	M8 x 1.25 mm	17 - 21 ft·lb (22.6 - 28.4 N·m; 2.3 - 2.9 kgf·m)	Not Applied
Fuel Pump Drive Gear Nut	4TNV98	M18 x 1.5 mm	83 - 90 ft·lb (113 - 123 N·m; 11.5 - 12.5 kgf·m)	Not Applied
High-Pressure Fuel Lines Bolt	4TNV98	M12 x 1.5 mm	174 - 217 in·lb (19.6 - 24.5 N·m; 2.0 - 2.5 kgf·m)	Not Applied
Fuel Return Line Joint Bolt	4TNV98	M6 x 1.0 mm	70 - 86 in·lb (7.8 - 9.8 N·m; 0.8 - 1.0 kgf·m)	Not Applied

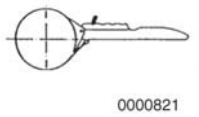
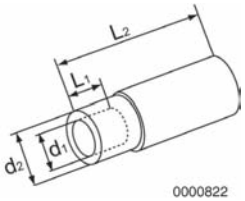
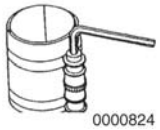
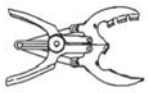
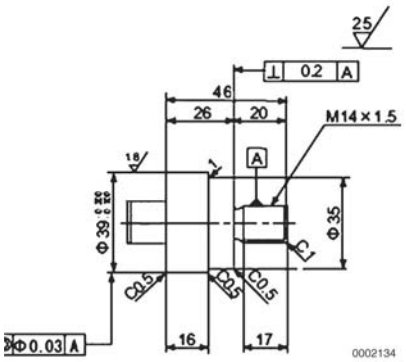
See Tightening Torques for Standard Bolts and Nuts on page 23 for standard hardware torque values.

Special Service Tools

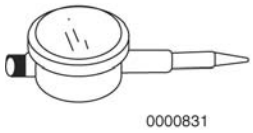
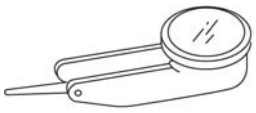
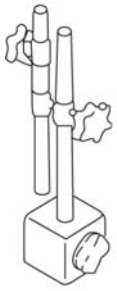
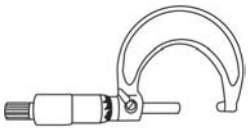
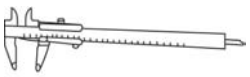
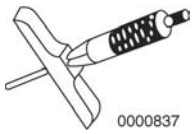
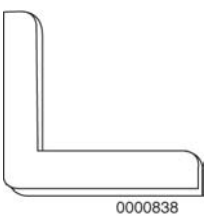
<table>
<tr><th>No.</th><th>Tool Name</th><th>Applicable Model and Tool Size</th><th>Illustration</th></tr>
<tr><td>1</td><td>Valve Guide Tool (For Removing Valve Guide)</td><td>
<table>
<tr><td>Model</td><td>L1</td><td>L2</td><td>d1</td><td>d2</td></tr>
<tr><td>4TNV98</td><td>0.787 in. (20 mm)</td><td>2.953 in. (75 mm)</td><td>0.256 in. (6.5 mm)</td><td>0.394 in. (10 mm)</td></tr>
<tr><td>4TNE98</td><td>0.787 in. (20 mm)</td><td>2.953 in. (75 mm)</td><td>0.295 in. (7.5 mm)</td><td>0.433 in. (11 mm)</td></tr>
<tr><td colspan="5">Locally Manufactured</td></tr>
</table>
</td><td> 
</td></tr>
<tr><td>2</td><td>Valve Guide Tool (For Installing Valve Guide)</td><td>
<table>
<tr><td>Model</td><td>L1</td><td>L2</td><td>d1</td><td>d2</td></tr>
<tr><td>4TNV98</td><td>0.276 in. (7 mm)</td><td>2.362 in. (60 mm)</td><td>0.512 in. (13 mm)</td><td>0.630 in. (16 mm)</td></tr>
<tr><td>4TNE98</td><td>0.591 in. (15 mm)</td><td>2.559 in. (65 mm)</td><td>0.551 in. (14 mm)</td><td>0.787 in. (20 mm)</td></tr>
<tr><td colspan="5">Locally Manufactured</td></tr>
</table>
</td><td> 
</td></tr>
<tr><td>4</td><td>Connecting Rod Bushing Replacer (For Removal/ Installation of Connecting Rod Bushing)</td><td>
<table>
<tr><td>L1</td><td>L2</td><td>d1</td><td>d2</td></tr>
<tr><td>0.787 in. (20 mm)</td><td>3.937 in. (100 mm)</td><td>1.181 in. (30 mm)</td><td>1.299 in. (33 mm)</td></tr>
<tr><td colspan="4">Locally Manufactured</td></tr>
</table>
</td><td> 
</td></tr>
<tr><td>5</td><td>Valve Spring Compressor (For Removal/ Installation of Valve Spring)</td><td>Yanmar Part No.
129100-92630</td><td> 
</td></tr>
<tr><td>6</td><td>Stem Seal Installer (for Installing Valve Stem Seal)</td><td>
<table>
<tr><td>Model</td><td>d1</td><td>d2</td><td>d3</td><td>L1</td><td>L2</td><td>L3</td></tr>
<tr><td>4TNV98</td><td>0.598 in. (15.2 mm)</td><td>0.827 in. (21 mm)</td><td>0.472 in. (12 mm)</td><td>0.465 in. (11.8 mm)</td><td>2.559 in. (65 mm)</td><td>0.157 in. (4 mm)</td></tr>
<tr><td>4TNE98</td><td>0.638 in. (16.2 mm)</td><td>0.866 in. (22 mm)</td><td>0.531 in. (13.5 mm)</td><td>0.669 in. (17.0 mm)</td><td>2.560 in. (65 mm)</td><td>0.157 in. (4 mm)</td></tr>
<tr><td colspan="7">Locally Manufactured</td></tr>
</table>
</td><td> 

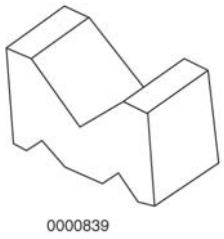
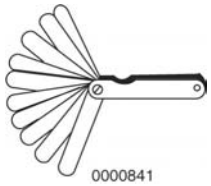
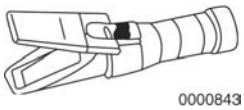
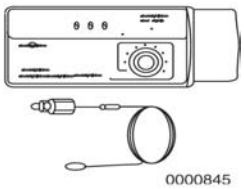
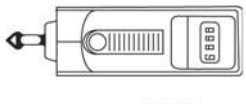
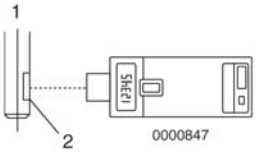

</td></tr>
</table>

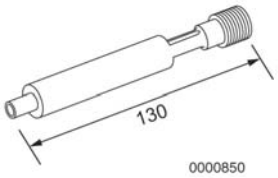
(Special Service Tools Cont.)

<table>
<tr><th>No.</th><th>Tool Name</th><th colspan="2">Applicable Model and Tool Size</th><th>Illustration</th></tr>
<tr><td>7</td><td>Filter Wrench (For Removal / Installation of Engine Oil Filter)</td><td colspan="2">Available Locally</td><td> 
0000821</td></tr>
<tr><td rowspan="4">8</td><td rowspan="4">Camshaft Bushing Tool (For Extracting Camshaft Bushing)</td><td colspan="2"></td><td rowspan="4"> 
0000822</td></tr>
<tr><td>L1</td><td>L2</td><td>d1</td><td>d2</td></tr>
<tr><td>0.709 in.
(18 mm)</td><td>2.756 in.
(70 mm)</td><td>1.968 in.
(50 mm)</td><td>2.087 in.
(553 mm)</td></tr>
<tr><td colspan="4">Allowance : $d1^{-0.3}_{-0.6}$, $d2^{-0.3}_{-0.6}$
Locally Manufactured</td></tr>
<tr><td rowspan="2">9</td><td rowspan="2">Flex-Hone (For Preparation of Cylinder Walls)</td><td colspan="2">Yanmar Part No.</td><td>Cylinder Bore</td><td rowspan="2">
0000823</td></tr>
<tr><td>129400-92440</td><td>3.504 - 3.976 in.
(89 - 101 mm)</td></tr>
<tr><td>10</td><td>Piston Ring Compressor (For Installing Piston)</td><td colspan="2">Yanmar Part No. 95550-002476
The Piston Insertion Tool is Applicable for 2.362 - 4.921 in.
(60 - 125 mm) Diameter Pistons</td><td> 
0000824</td></tr>
<tr><td>11</td><td>Piston Ring Expander (For Removal / Installation of Piston Ring)</td><td colspan="2">Available Locally</td><td> 
0000825</td></tr>
<tr><td>12</td><td>Crankshaft Pulley Installing Tool</td><td>Locally Manufactured</td><td> 
0002134</td><td>
0000826</td></tr>
</table>

Measuring Instruments

No.	Instrument Name		Application	Illustration
1	Dial Indicator	Locally Available	Measure shaft bend and end play	 0000831
2	Test Indicator	Locally Available	Measurements of narrow or deep portions that cannot be measured by dial gauge	 0000832
3	Magnetic Stand	Locally Available	For holding the dial gauge when measuring	 0000833
4	Micrometer	Locally Available	For measuring the outside diameters of crankshaft, pistons, piston pins, etc.	 0000834
5	Cylinder Bore Gauge	Locally Available	For measuring the inside diameters of cylinder liners, bearing bores, etc.	0000835
6	Calipers	Locally Available	For measuring outside diameters, depth, thickness and width	 0000836
7	Depth Micrometer	Locally Available	For measuring of valve recession	 0000837
8	Square	Locally Available	For measuring valve spring inclination and straightness of parts	 0000838

No.	Instrument Name		Application	Illustration
9	V-Block	Locally Available	For measuring shaft bend	 0000839
10	Torque Wrench	Locally Available	For tightening nuts and bolts to the specified torque	0000840
11	Feeler Gauge	Locally Available	For measuring piston ring gaps, piston ring clearance, and valve adjustment clearance	 0000841
12	Battery Coolant Tester		For checking concentration of antifreeze and the battery electrolyte charge status	 0000843
13	Digital Thermometer		For measuring temperatures	 0000845
14	Tachometer	Contact Type	For measuring revolution by contacting the revolving shaft	 0000846
		Photoelectric Type	For measuring revolution by sensing the reflecting mark on the outer periphery of the revolving shaft	 0000847
		Fuel High Pressure Pipe Clamp Type	This measures the revolution regardless of the center or periphery of the revolving object	

No.	Instrument Name	Application	Illustration
15	Circuit Tester	For measuring resistance, voltage and continuity of electrical circuits	
16	Compression Gauge Kit	For measuring compression pressureGauge Set Part No. TOL-97190080	
	New Comperssion Test Adaptor	Adapter for direct injection 2-valve cylinder headAdapter Part No. 119802-92950	

Cylinder Head

Cylinder Head Components

4TNV98 Engine

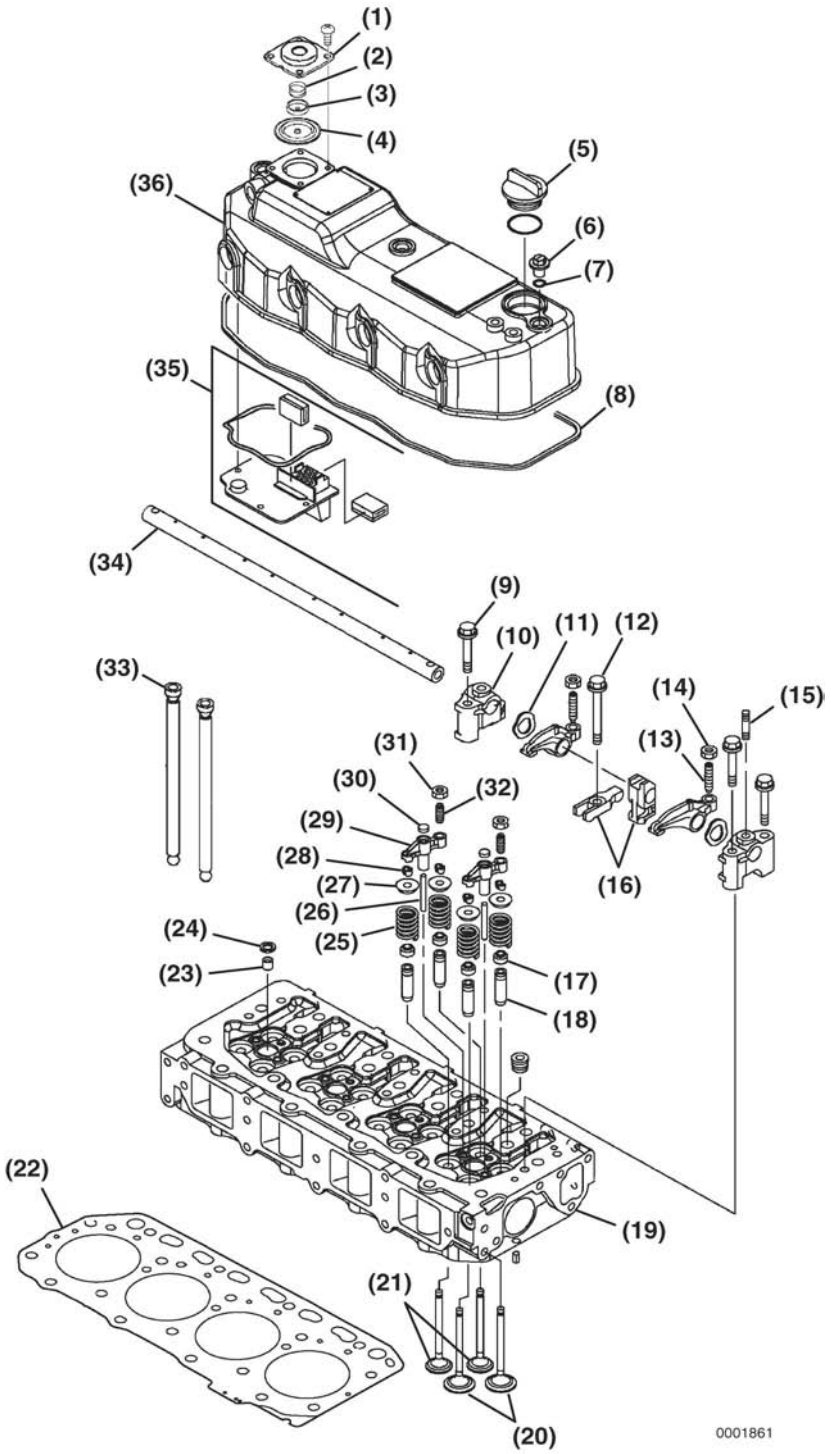


Figure 6-36

(1) Crankcase Breather Cover.
(2) Diaphragm Spring.
(3) Diaphragm Cup.
(4) Crankcase Breather Diaphragm.
(5) Oil Fill Cap.
(6) Valve Cover Nut.
(7) Valve Cover Nut O-Ring .
(8) Valve Cover Gasket.
(9) Support Bolt.
(10) Rocker Arm Shaft Support.
(11) Wave Washer.
(12) Fuel Injector Retainer Bolt.
(13) Valve Adjusting Screw (Primary).
(14) Valve Adjusting Screw Lock Nut (Primary).
(15) Rocker Arm Shaft Aligning Stud.
(16) Fuel Injector Retainer.
(17) Valve Stem Seal.
(18) Valve Guide.
(19) Cylinder Head.
(20) Intake Valve.
(21) Exhaust Valve.
(22) Cylinder Head Gasket.
(23) Fuel Injector Nozzle Protector.
(24) Fuel Injector Nozzle Seat.
(25) Valve Spring.
(26) Valve Bridge Guide.
(27) Spring Retainer.
(28) Valve Keepers.
(29) Valve Bridge.
(30) Valve Bridge Seat.
(31) Valve Adjusting Screw Lock Nut (Secondary).
(32) Valve Adjusting Screw (Secondary).
(33) Push Rod.
(34) Rocker Arm Shaft.
(35) Crankcase Breather Components.
(36) Valve Cover.

Disassembly of 4-Valve Cylinder Head

Prepare a clean, flat working surface on a workbench large enough to accommodate the cylinder head assembly. Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of the cylinder head.

1. Drain the coolant from the engine into a suitable container. See Drain, Flush and Refill Cooling System with New Coolant on page 163.

CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

2. Remove the high pressure fuel injection lines **(Figure 6-37, (1))**. See Removal of Fuel Injectors on page7-31.

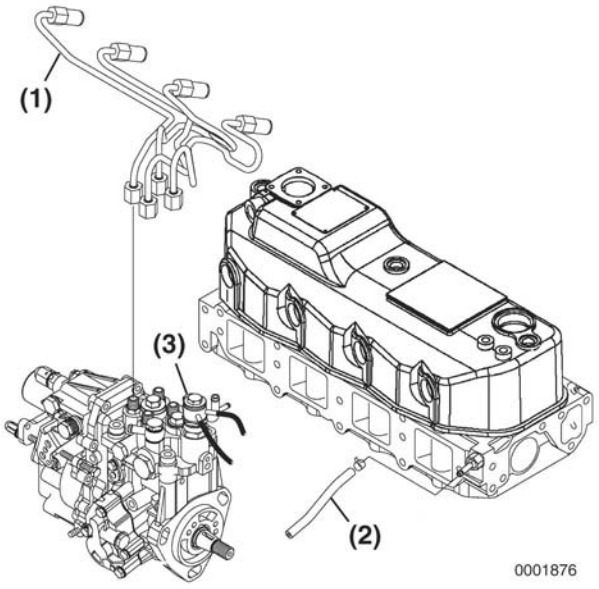


Figure 6-37

CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

3. Disconnect the fuel return hose **(Figure 6-37, (2))** from the cylinder head.

4. Disconnect the hoses **(Figure 6-37, (3))** from the cold start device on the fuel injection pump.

5. Remove the turbocharger-to-intake manifold hose **(Figure 6-38, (1))** (if equipped).

6. Disconnect the electrical wire from the intake air heater **(Figure 6-38, (12))**.

7. Remove the intake manifold bolts **(Figure 6-38, (11))**. Remove the intake manifold **(Figure 6-38, (10))**. Discard the intake manifold gasket **(Figure 6-38, (9))**.

8. Remove the exhaust manifold bolts **(Figure 6-38, (7))**. Remove the exhaust manifold **(Figure 6-38, (6))** with the turbocharger attached. Discard the exhaust manifold gasket. **(Figure 6-38, (5))**.

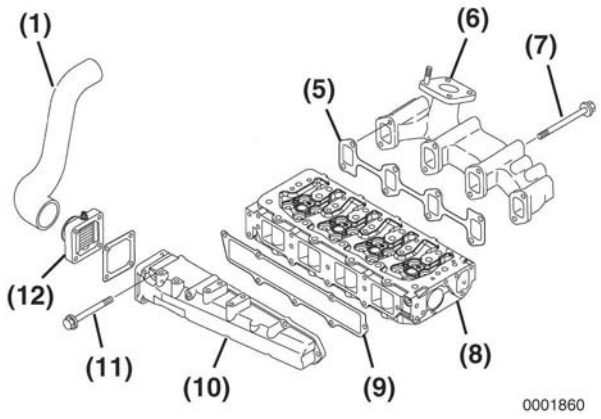


Figure 6-38

10. Remove the engine coolant pump. See Disassembly of Engine Coolant Pump on page 207.

Removal of Valve Cover

NOTE: The high pressure fuel injection lines and valve cover grommets must be removed prior to removing the valve cover. See Removal of Fuel Injectors on page 163.

1. Remove the high-pressure fuel lines.

2. Use a flat-blade screwdriver **(Figure 6-39)** to remove the fuel injection line grommets **(Figure 6-40, (1))** from the valve cover **(Figure 6-40, (3))** and fuel injectors **(Figure 6-40, (2))**. There is a notch at the 3 o'clock position in the valve cover opening to insert the screwdriver.

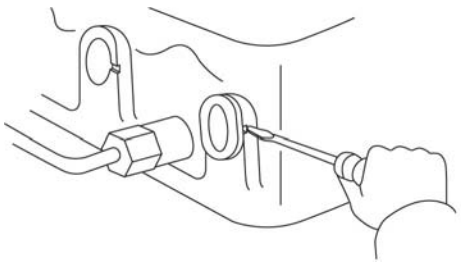


Figure 6-39

3. Remove the valve cover nuts **(Figure 6-40, (4))**.

4. Remove the O-ring **(Figure 6-40, (5))** on each valve cover nut.

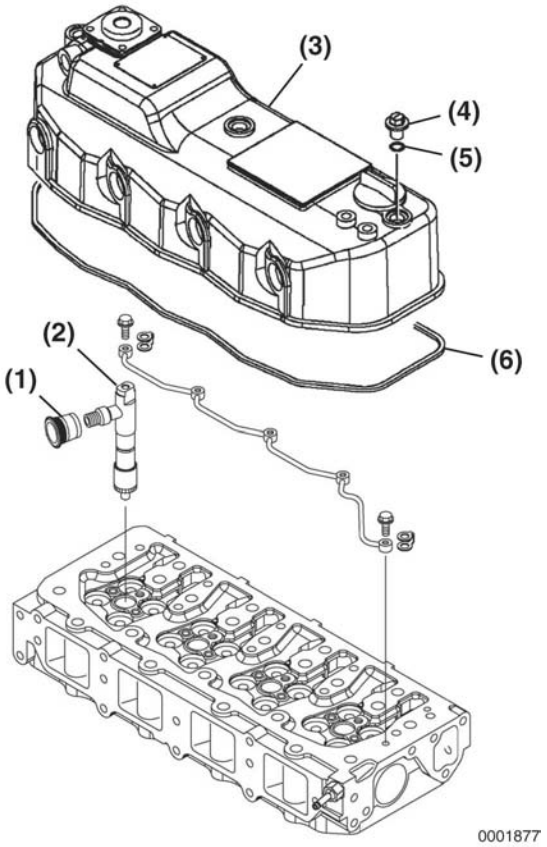


Figure 6-40

5. Remove the valve cover **(Figure 6-40, (3))**. Discard the valve cover gasket **(Figure 6-40, (6))**.

6. Inspect and clean the crankcase breather assembly. See Inspect Crankcase Breather System on page 61.

Removal of Rocker Arm Assembly

1. Remove the fuel injectors from the cylinder head. See Removal of Fuel Injectors on page 163.

2. Remove the bolts **(Figure 6-41, (1))** that retain the rocker arm shaft supports to the cylinder head.

3. Remove the rocker arm and shaft assembly from the cylinder head.

NOTE : Identify the push rods and valve bridges so they can be installed in their original locations.

4. Remove the push rods **(Figure 6-41, (2))**.

5. Remove the valve bridge assemblies **(Figure 6-41, (3))**. Remove the seat **(Figure 6-41, (4))** from each valve bridge.

6. Identify all parts so that they will be reinstalled in their original locations.

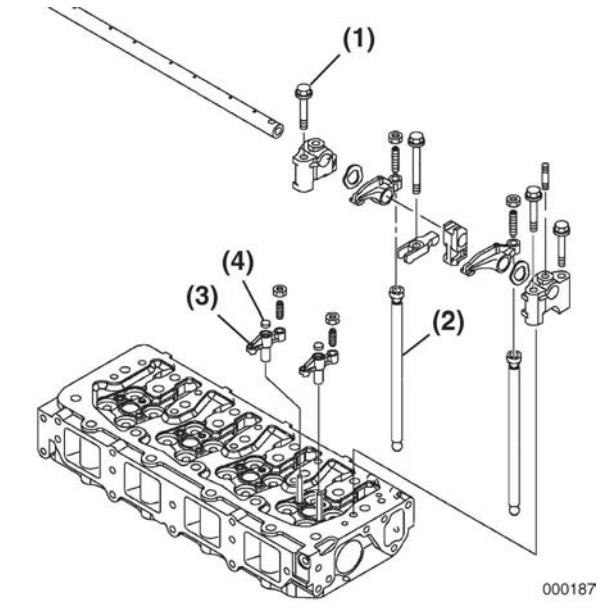


Figure 6-41

Disassembly of Rocker Arm Assembly

NOTE : Identify the rocker arms so they can be reinstalled with the original matching valve and pushrod.

1. Remove the rocker arm shaft alignment studs **(Figure 6-42, (5))** from the rocker arm shaft supports **(Figure 6-42, (6))**.

2. Slide the supports, wave washers **(Figure 6-42, (7))**, rocker arms **(Figure 6-42, (8))**, and fuel injector retainers **(Figure 6-42, (4))** off the rocker shaft **(Figure 6-42, (1))**, leaving these parts in order on the bench surface.

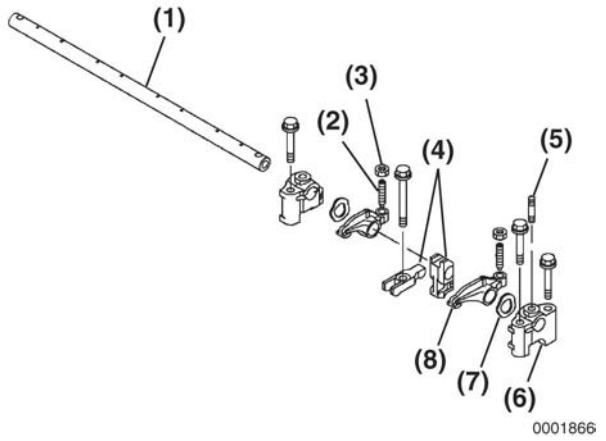


Figure 6-42

NOTE : **Figure 6-42** shows components for one cylinder. Components for all remaining cylinders are assembled in the same order.

3. Remove the valve adjusting screw **(Figure 6-42, (2))** and the lock nut **(Figure 6-42, (3))** from the rocker arms.

Removal of Cylinder Head

1. Loosen the cylinder head bolts following the sequence shown in **(Figure 6-43)**.

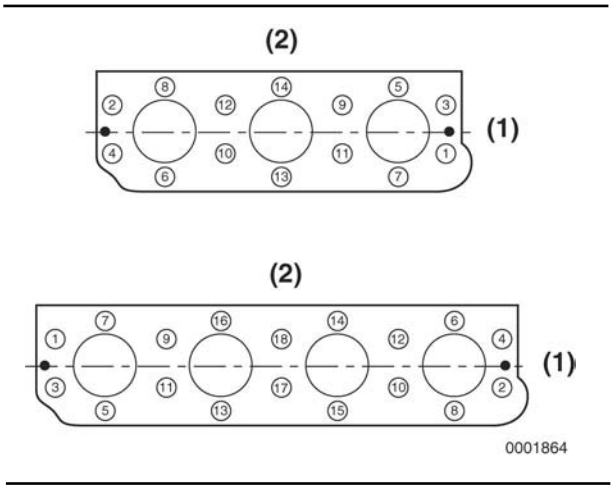


Figure 6-43

1) Cooling Fan End
2) Camshaft Side

2. Remove the cylinder head bolts **(Figure 6-44, (1))**.

3. Lift the cylinder head away from the cylinder block. Discard the cylinder head gasket **(Figure 6-44, (2))**. Place the cylinder head on the work bench to prevent damage to the combustion surface.

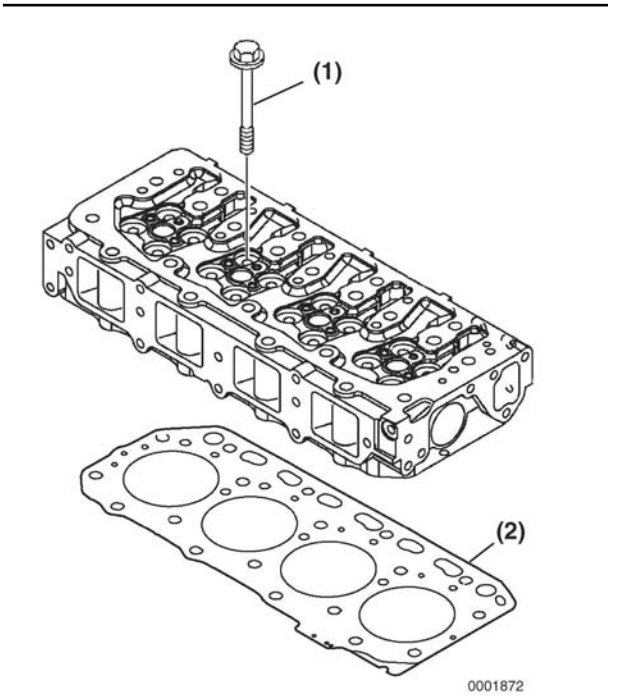


Figure 6-44

Removal of Intake and Exhaust Valves

1. Place the cylinder head on the work bench with the combustion side down.

2. Using the valve spring compressor tool, compress one of the valve springs **(Figure 6-45)**.

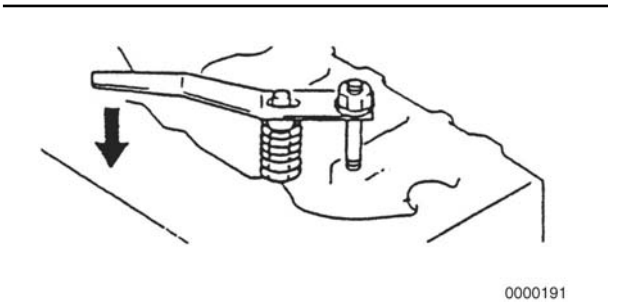


Figure 6-45

3. Remove the valve keepers **(Figure 6-46, (1))**.

4. Slowly release the tension on the valve spring.

5. Remove the spring retainer **(Figure 6-46, (2))**, valve spring **(Figure 6-46, (3))**.

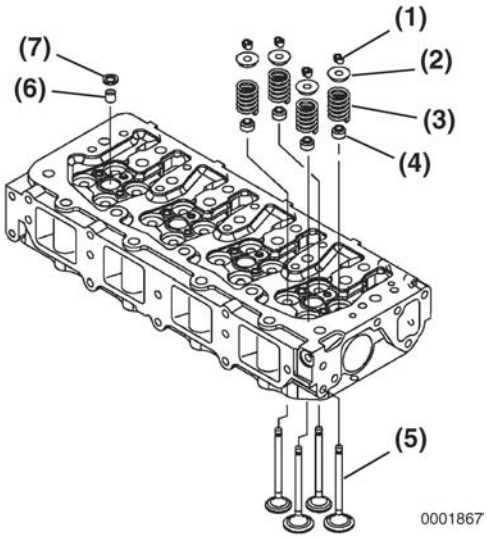


Figure 6-46

6. Repeat the procedure with all the remaining valves.

NOTE : If the valves are to be reused, identify them so they can be installed in their original location.

7. Remove the injector nozzle protectors **(Figure 6-46, (6))** and the seats **(Figure 6-46, (7))**.

8. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves **(Figure 6-46, (5))** from the cylinder head.

9. Remove the valve stem seals **(Figure 6-46, (4))**.

Removal of Valve Guides

NOTE : Removal of the valve guides should be postponed until inspection and measurement procedures have been performed. See Inspection of Valve Guides on page 94.

1. Using a drift pin and hammer, drive the valve guides **(Figure 6-47, (1))** out of the cylinder head.

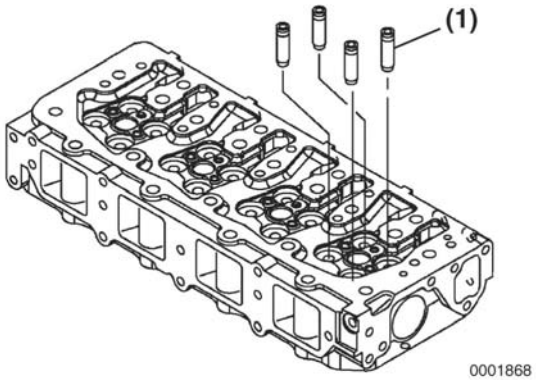


Figure 6-47

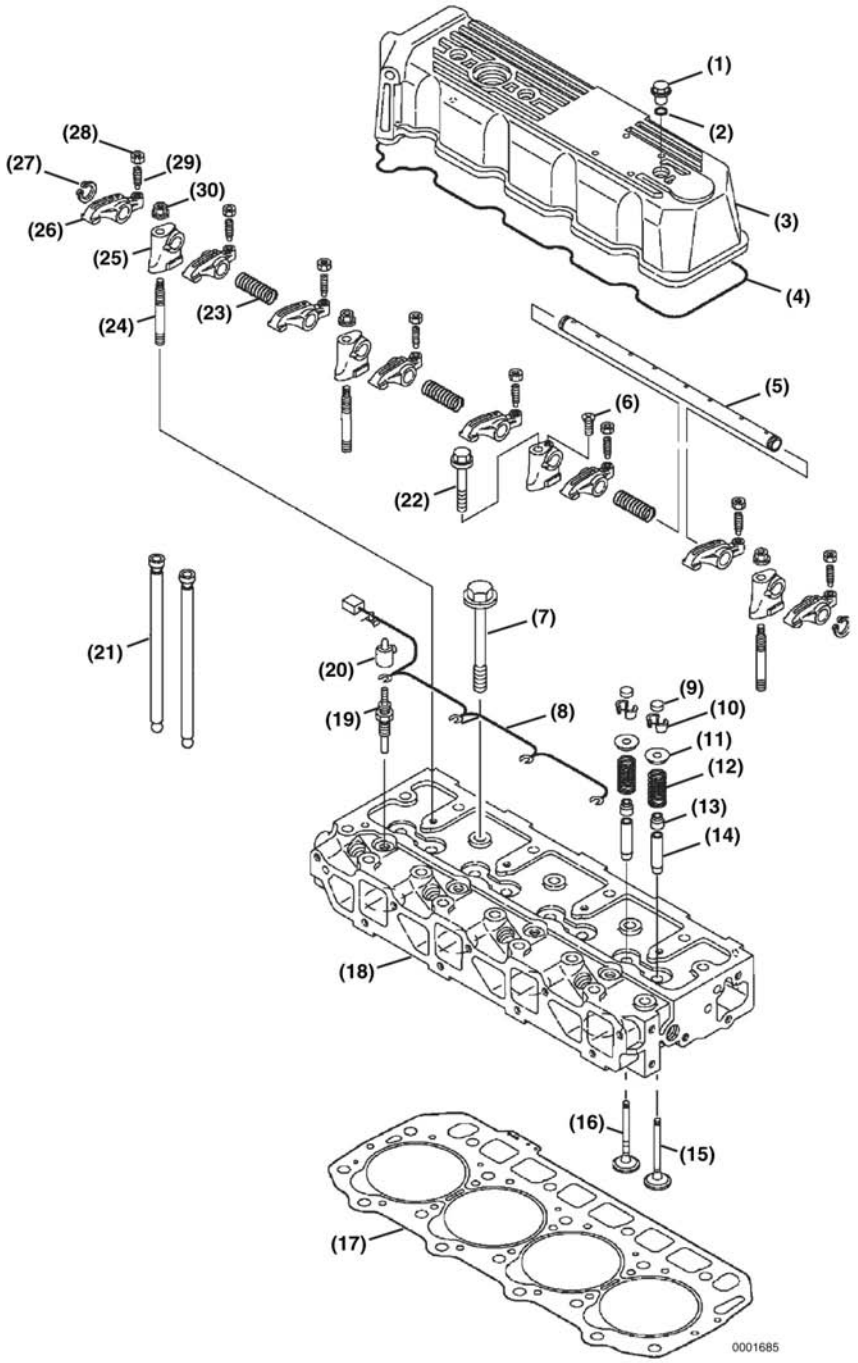

(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
(15)
(16)
(17)
(18)
(19)
(20)
(21)
(22)
(23)
(24)
(25)
(26)
(27)
(28)
(29)
(30)
0001685

Figure 6-1

(1) Valve Cover Nut
(2) Valve Cover Nut O-ring
(3) Valve Cover
(4) Valve Cover Gasket
(5) Rocker Arm Shaft
(6) Rocker Arm Shaft Retaining Screw
(7) Cylinder Head Bolt
(8) Glow Plug Harness
(9) Valve Cap
(10) Valve Keepers
(11) Spring Retainer
(12) Valve Spring
(13) Valve Stem Seal
(14) Valve Guide
(15) Intake Valve
(16) Exhaust Valve
(17) Cylinder Head Gasket
(18) Cylinder Head
(19) Glow Plug
(20) Glow Plug Cover
(21) Push Rod
(22) Support Bracket Bolt
(23) Rocker Arm Shaft Spring
(24) Support Bracket Stud
(25) Support Bracket
(26) Rocker Arm
(27) Rocker Arm Shaft Retaining Ring
(28) Valve Adjusting Screw Lock Nut
(29) Valve Adjusting Screw
(30) Support Bracket Nut

Disassembly of Cylinder Head

Prepare a clean, flat working surface on a workbench large enough to accommodate the cylinder head assembly. Discard all gaskets, O-rings and seals.

CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the assembly process.

0000080en

1. Remove the intake manifold bolts **(Figure 6-2, (1))**. Remove the intake manifold **(Figure 6-2, (3))**. Discard the intake manifold gasket **(Figure 6-2, (3))**.

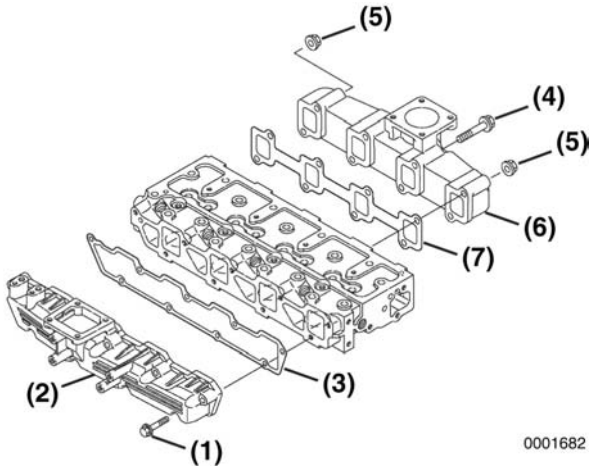


Figure 6-2

2. Remove the exhaust manifold bolts **(Figure 6-2, (4))** and nuts **(Figure 6-2, (5))**. Remove the exhaust manifold **(Figure 6-2, (6))**. Discard the exhaust manifold gasket **(Figure 6-2, (7))**.

3. Remove the water pump from the engine. See Disassembly of Engine Coolant Pump on 205.

4. Remove the fuel injectors from the cylinder head. See Removal of the Fuel Injectors on page 196.

Removal of Glow Plugs

1. Remove the glow plug cover **(Figure 6-3, (2))** from each of the glow plugs **(Figure 6-3, (1))**.

2. Disconnect the glow plug harness **(Figure 6-3, (3))** from the glow plugs.

3. Remove the glow plugs from the cylinder head **(Figure 6-3, (4))**.

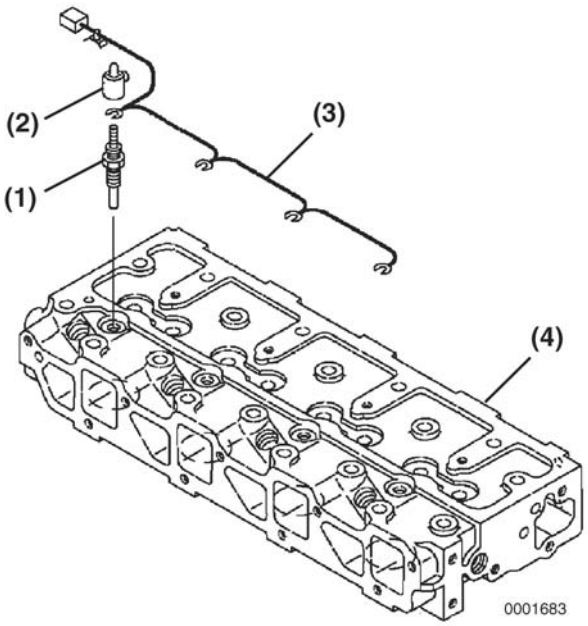


Figure 6-3

Removal of Valve Cover

1. Remove the valve cover nuts **(Figure 6-4, (1))**.

2. Check the condition of the O-ring **(Figure 6-4, (2))** on each valve cover nut. Replace the O-ring if necessary.

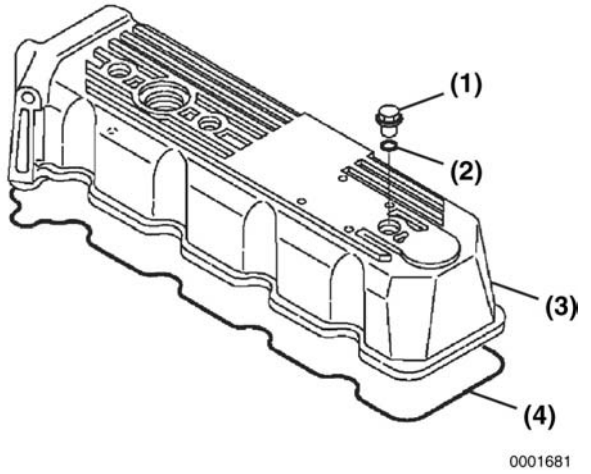


Figure 6-4

3. Remove the valve cover **(Figure 6-4, (3))**. Discard the valve cover gasket **(Figure 6-4, (4))**.

Removal of Rocker Arm Assembly

1. Remove the bolt **(Figure 6-6, (1))** and locking nuts **(Figure 6-6, (2))** that retain the rocker arm support brackets to the cylinder head.

2. Lift the rocker arm assembly from the cylinder head.

3. Lift the push rods from the cylinder head.

4. Number the push rods so that they are reinstalled with the same valve tappet and rocker arm.

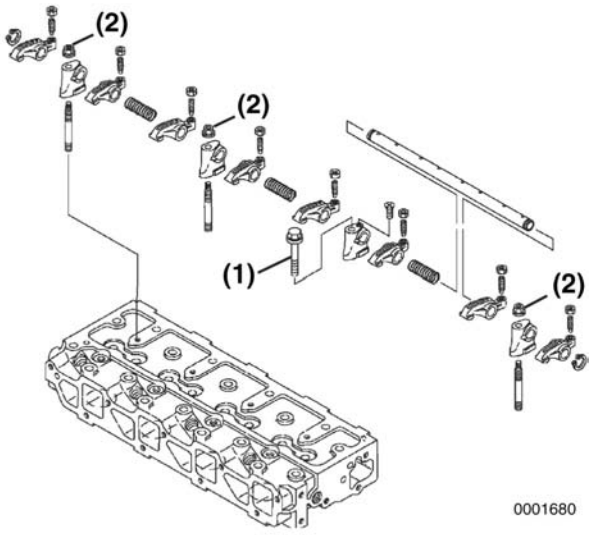


Figure 6-6

Disassembly of Rocker Arm Assembly

1. Remove the rocker arm shaft alignment screw **(Figure 6-7, (1))** from the support bracket that secures the rocker arm shaft **(Figure 6-7, (2))**.

2. Remove the retaining rings **(Figure 6-7, (3))** from the ends of the rocker arm shaft **(Figure 6-7, (2))**.

3. Slide the rocker arm shaft **(Figure 6-7, (2))** out of the rocker arm support brackets **(Figure 6-7, (4))**, springs **(Figure 6-7, (5))**, and rocker arms **(Figure -7, (6))**.

NOTE : The rocker arm shaft fits tightly in the rocker arm support brackets. Clamp the support bracket in a padded vise and twist the rocker arm shaft to remove. Reverse this process when you reinstall the rocker arm shaft into the support brackets.

NOTE : Mark the rocker arms so they can be reinstalled with the original matching valve and pushrod.

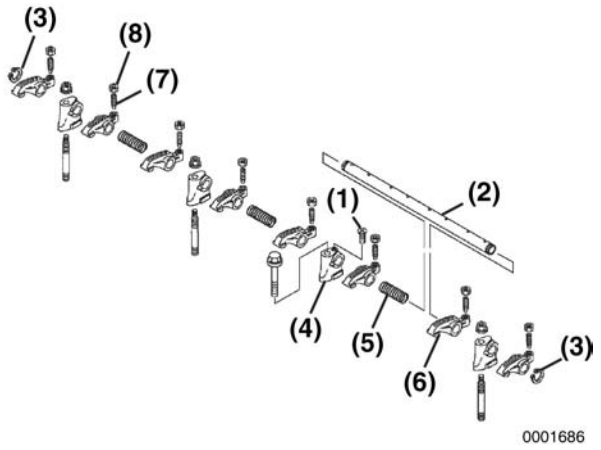
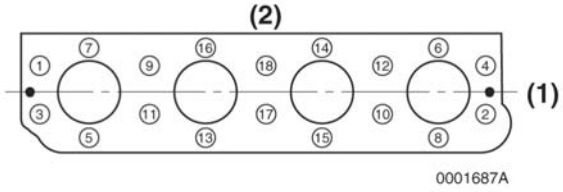


Figure 6-7

4. .If necessary, remove the valve adjusting screw **(Figure 6-7, (7))** and lock nut **(Figure 6-7, (8))** from the rocker arms.

Removal of Cylinder Head

1. Loosen the cylinder head bolts following the sequence shown in **(Figure 6-8)**.



1. Fan Side
2. Camshaft Side

Figure 6-8

2. Remove the cylinder head bolts **(Figure 6-9, (1))**.

3. Lift the cylinder head away from the cylinder block. Discard the cylinder head gasket **(Figure 6-9, (2))**. Position the cylinder head on the work bench to prevent damage to the combustion surface.

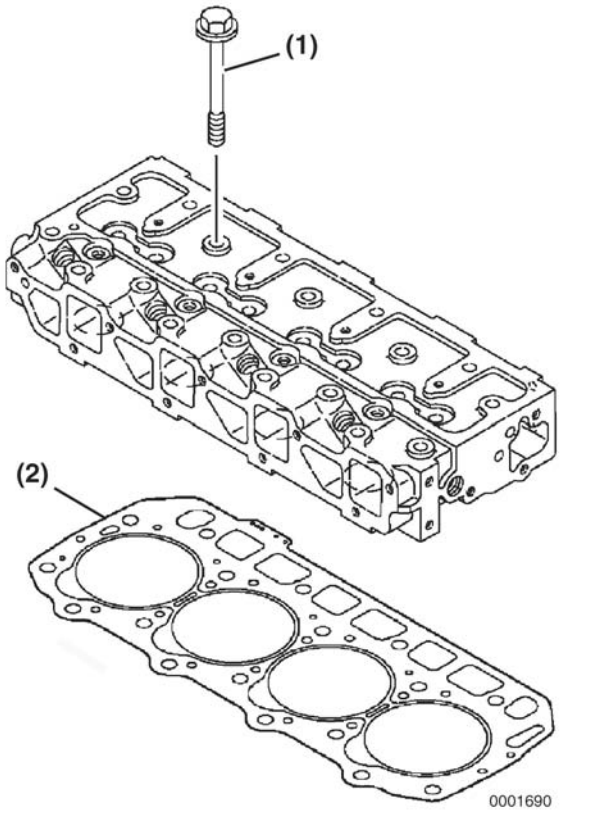


Figure 6-9

Removal of Intake / Exhaust Valves

1. Place the cylinder head on the work bench with the combustion side down.

2. Using the valve spring compressor tool, compress one of the valve springs **(Figure 6-10)**.

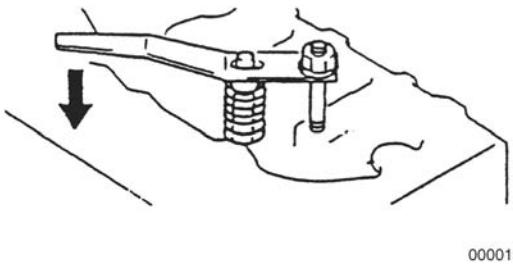


Figure 6-10

3. Remove the valve keepers **(Figure 6-11, (2))** and valve cap **(Figure 6-10, (1))** from the end of the valve.

4. Slowly release the tension on the valve spring.

5. Remove the spring retainer **(Figure 6-11, (3)),** valve spring **(Figure 6-11, (4))** and valve stem seal **(Figure 6-11, (5))**.

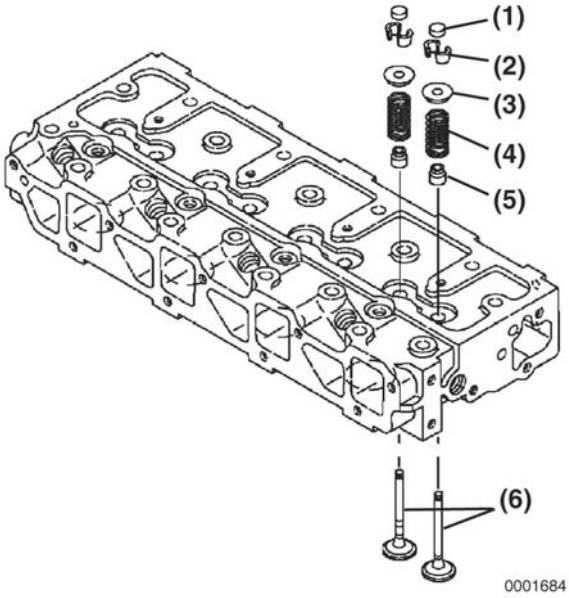


Figure 6-11

6. Repeat this procedure until all the intake and exhaust valve springs and valve stem seals are removed.

NOTE : If you are going to reinstall the valves in the cylinder head, mark them so they can be installed in their original location.

7. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves **(Figure 6-11, (6))** from the cylinder head.

Removal of Valve Guides

1. Using a drift pin and hammer, drive the valve guides **(Figure 6-12, (1))** out of the cylinder head.

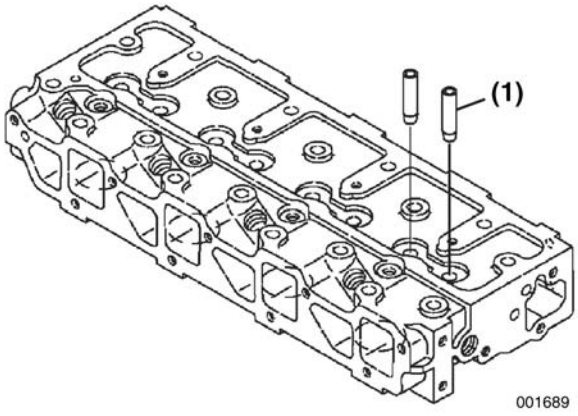


Figure 6-12

Cleaning of Cylinder Head Components

⚠ WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

Thoroughly clean all components using a non-metallic brush and an appropriate solvent. Each part must be free of carbon, metal filings and other debris.

Inspection of Cylinder Head Components

Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted or otherwise damaged. Discard any parts that do not meet its specified limit.

CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

CAUTION

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

Inspection of Push Rods

Push Rod Bend

1. Place the push rods on a flat inspection block or layout bed.

2. Roll the push rods until a gap can be observed between a portion of the push rod and the surface of the block or layout bed.

3. Use a feeler gauge to measure the gap **(Figure 6-48)**. See Push Rod on page 68 for the service limit.

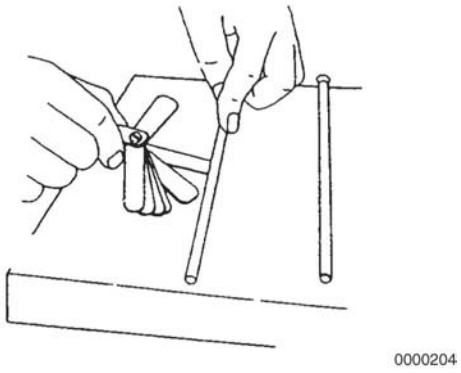


Figure 6-48

Inspection of Rocker Arm Assembly

Rocker Arm Shaft Hole Diameter

1. Use a telescoping gauge and micrometer to determine if the inside diameter of all the rocker arm support brackets and the rocker arms **(Figure 6-49)** are within the specified limits. See Rocker Arm and Shaft on page 68 for the service limit.

2. Inspect the contact areas **(Figure 6-49, (1))** for excessive wear or damage.

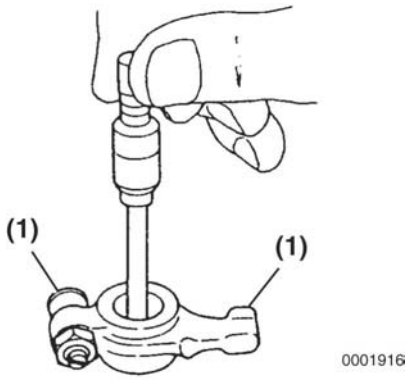


Figure 6-49

Rocker Arm Shaft Outside Diameter

Use a micrometer to measure the rocker arm shaft diameter **(Figure 6-50)**. Measure at each rocker arm location in two directions 90° apart **(Figure 6-50)**. See Rocker Arm and Shaft on page 68 for the service limit.

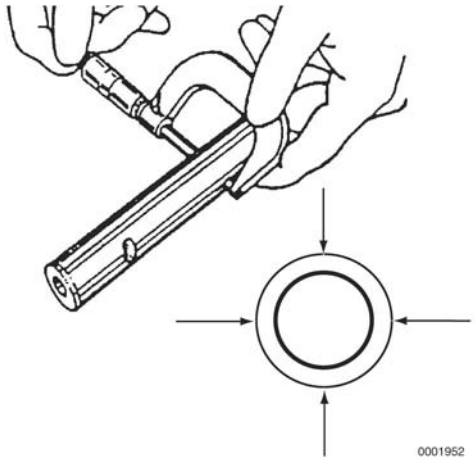


Figure 6-50

Inspection of Valve Guides

Valve Guide Inside Diameter

Visually inspect the valve guides for distortions, scoring or other damage.

NOTE : Measure the valve guides while they are installed in cylinder head.

Use a telescoping gauge and micrometer to measure the inside diameter at each end of the valve guide. Measure in three places and 90° apart **(Figure 6-51)**. See Intake/Exhaust Valve and Guide on page 67 for the service limit. Replace the valve guides if not within specification.

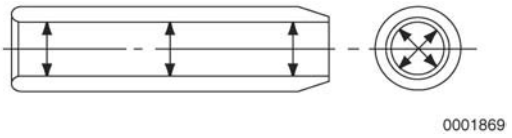


Figure 6-51

Inspection of Cylinder Head

Cylinder Head Distortion

Place the cylinder head flat and inverted (combustion side up) on the bench. Use a straight edge and feeler gauge to measure cylinder head distortion **(Figure 6-52)**. Measure diagonally and along each side. See Cylinder Head on page 66 for the service limit.

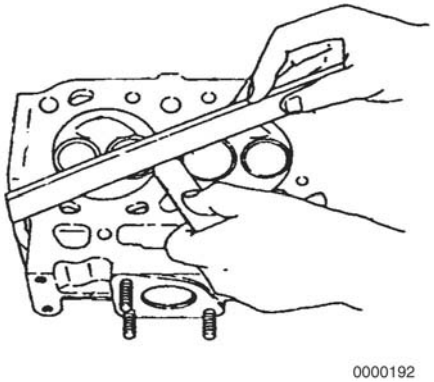


Figure 6-52

If distortion exceeds the service limit, resurface or replace the cylinder head. Remove only enough material to make the cylinder head flat, but do not remove more than 0.008 in (0.20 mm).

Inspection of Intake and Exhaust Valves

Visually inspect the intake and exhaust valves. Replace any valves that are obviously discolored, heavily pitted or otherwise damaged.

Valve Stem Diameter

Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end (Figure 6-53, (1)). See Intake/Exhaust Valve and Guide on page 67 for the service limit.

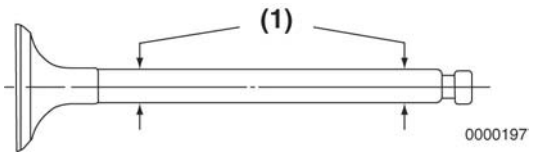


Figure 6-53

Valve Stem Bend

Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the block or bed. Use a feeler gauge to measure the gap **(Figure 6-54)**. See Intake/Exhaust Valve and Guide on page 67 for the service limit.

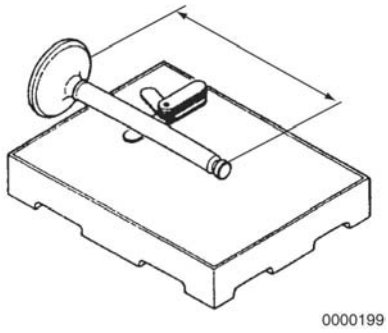


Figure 6-54

Valve Recession

NOTE: The valve guides must be installed to perform this check.

Insert the valves into their original locations and press them down until they are fully seated. Use a depth micrometer **(Figure 6-55)** to measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve **(Figure 6-56)**. See Cylinder Head on page 66 for the service limit.

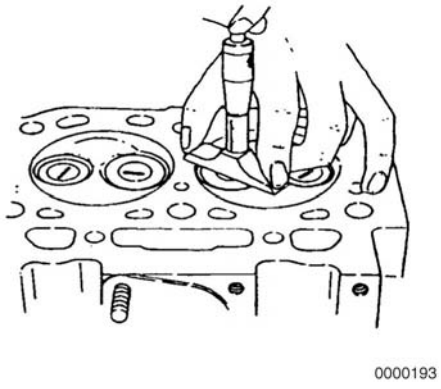


Figure 6-55

NOTE : 2-Valve cylinder head is shown. 4-Valve cylinder head is similar.

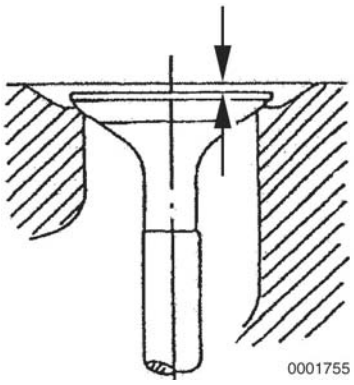


Figure 6-56

Valve Face and Valve Seat

Always check the clearance between the valve and valve guide before grinding or lapping the valve seats. See Intake/Exhaust Valve and Guide on page 67 for the service limit. If the clearance exceeds the limit, replace the valve and/or valve guide to bring the clearance within the limit.

Roughness or burrs will cause poor seating of a valve. Visually inspect the seating surfaces of each valve and valve seat to determine if lapping or grinding is needed.

Visually inspect all valves faces and valve seats for pitting, distortion, cracking, or evidence of overheating. Usually the valves and valve seats can be lapped or ground to return them to serviceable condition. Severely worn or damaged components will require replacement.

Coat the valve seat with a thin coat of bluing compound. Install the valve and rotate to distribute bluing onto the valve face. The contact pattern should be approximately centered on the valve face **(Figure 6-57, (1))** and even in width.

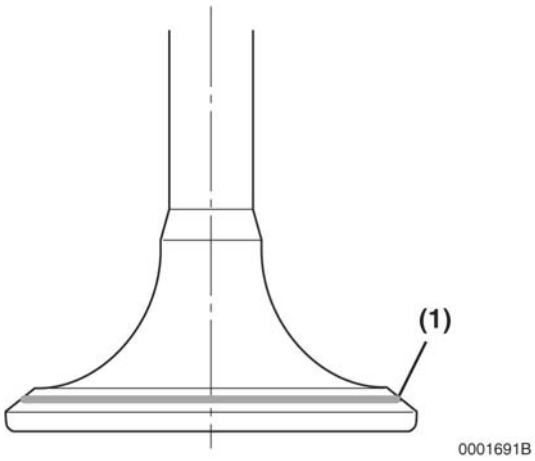


Figure 6-57

Also visually inspect the valve seat for even contact.

Light cutting can be performed by the use of a hand-operated cutter **(Figure 6-58)**.

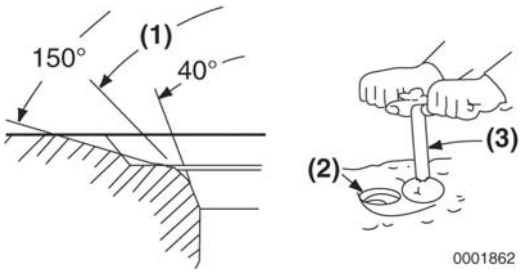


Figure 6-58

Valve seat diameter can be adjusted by top-grinding with a 150° stone to make the seat diameter smaller, and bottom-grinding using a 40° stone to make the seat diameter larger. Once the seat location has been corrected, grind and lap the seat angle **(Figure 6-58, (1))** to specification. See Cylinder Head on page 66 for specifications.

Grind the valve face and/or valve seat as necessary to return them to serviceable condition. Grinding is needed if the valve and valve seat do not contact correctly. Check the valve margin and valve recession after grinding.

If the valve or seat require grinding, lap the valve after grinding. Lap the valve face to the valve seat using a mixture of valve lapping compound and engine oil.

Be sure to thoroughly wash all parts to remove all grinding powder or compound.

Inspection of Valve Springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.

Fractures

Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the valve spring.

Corrosion

Check for corrosion of spring material caused by oxidation.

Squareness

Use a flat surface and a square to check each spring for squareness **(Figure 6-59)**. See Valve Spring on page 68 for the service limit.

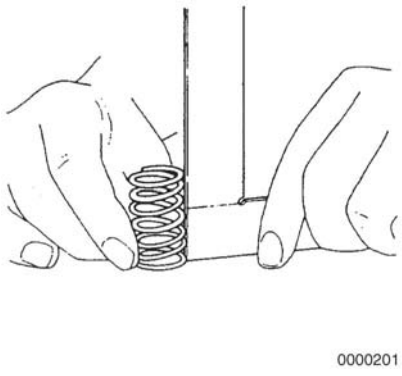


Figure 6-59

Free Length

Use a caliper to measure the length of the spring **(Figure 6-60)**. See Valve Spring on page 68 for the service limit.

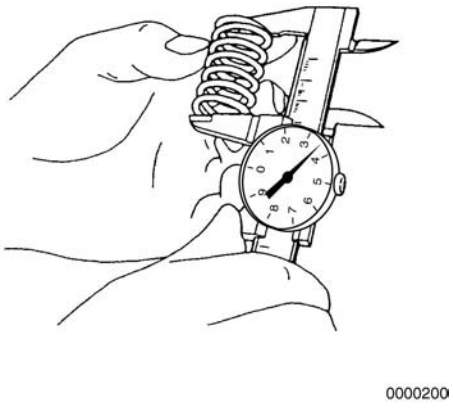


Figure 6-60

Inspection of Valve Bridges

4TNV98 Engine Only

Visually inspect the contact surface at both ends of the valve bridge **(Figure 6-61, (2))** for excessive wear or mushrooming.

Remove and inspect the seat **(Figure 6-61, (1))**.

Measure the diameter of the valve bridge guide pin bore in the valve bridge and guide pin **(Figure 6-61, (3))**. See Rocker Arm and Shaft on page 68 for the service limit.

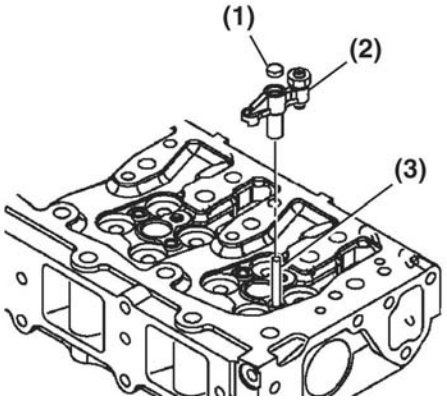


Figure 6-61

Reassembly of Cylinder Head

Use new gaskets, O-rings, and seals on reassembly of the cylinder head.

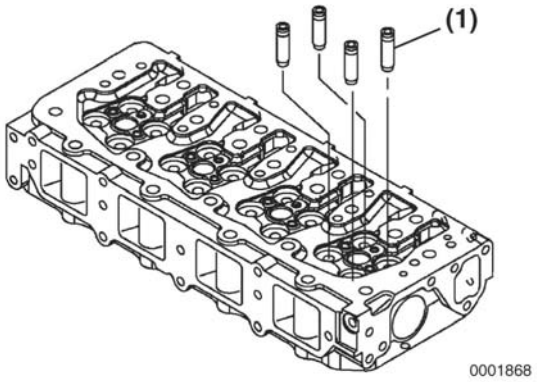
IMPORTANT
Liberally oil all components during reassembly to prevent premature wear or damage.

Reassembly of Valve Guides

1. The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in a freezer for at least twenty minutes This will cause the valve guides to contract, making it easier to install the valve guides into place.

2. Immediately after removing the valve guides from the freezer, insert the valve guides **(Figure 6-62, (1))** in their proper positions.

4TNV98 Engine



4TNE98 Engine

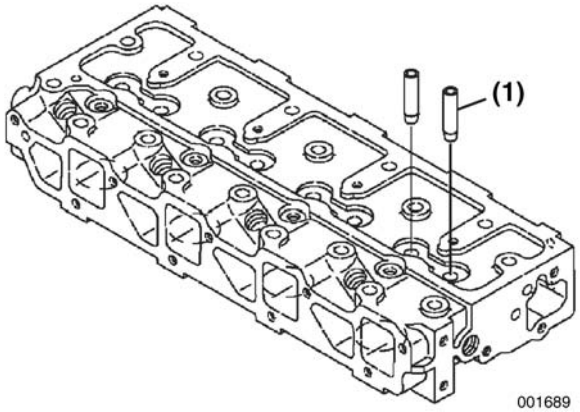


Figure 6-62

3. Finish installing the valve guides **(Figure 6-63, (1))** into the cylinder head to the proper height **(Figure 6-63, (3))** using the valve guide installation tool **(Figure 6-63, (2))**. See Intake/Exhaust Valve and Guide on page 67.

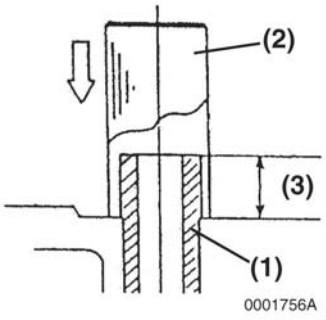


Figure 6-63

Reassembly of Intake and Exhaust Valves

IMPORTANT
Always install new valve stem seals. The exhaust valve seals can be identified by having yellow paint. Ensure they are installed in the correct locations.

1. Oil the lip of the valve stem seal **(Figure 6-64, (2))**. Using the valve stem seal installation tool **(Figure 6-64, (1))**, install a new valve stem seal on each of the valve guides **(Figure 6-64, (3))**.

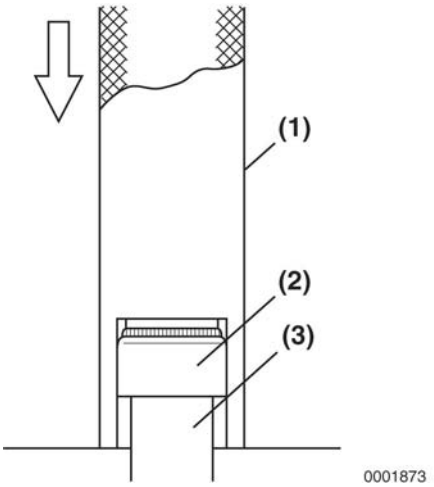


Figure 6-64

2. Measure the distance **(Figure 6-65, (1))** from the cylinder head to the valve stem seal to ensure proper clearance **(Figure 6-65, (2))** between the guide and seal. See Intake/Exhaust Valve and Guide on page 67.

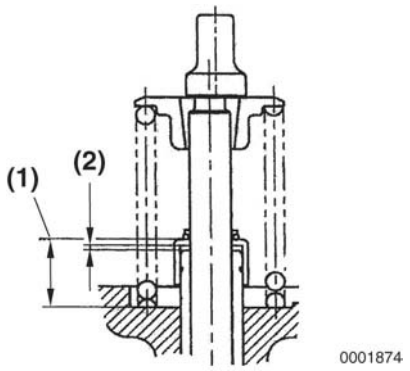
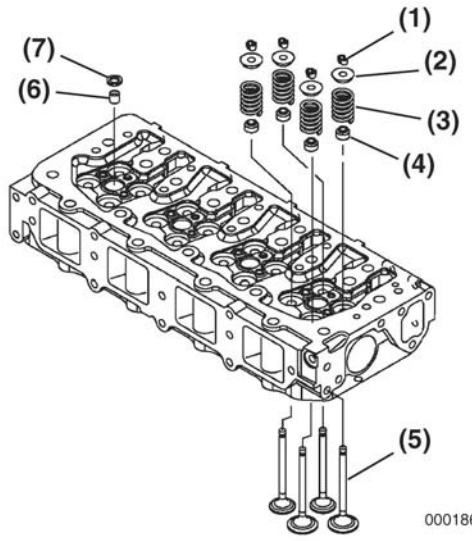


Figure 6-65

3. Place the cylinder head assembly on its exhaust port side.

4. Place all the valves **(Figure 6-66, (5))** in their proper location in the cylinder head.

4TNV98 Engine



4TNE98 Engine

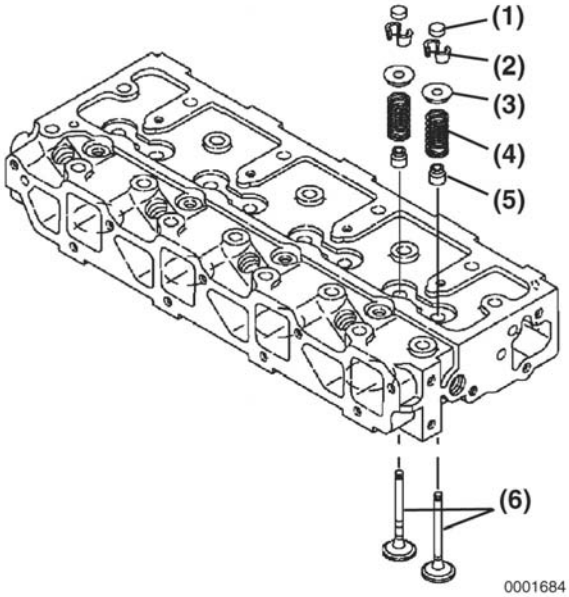


Figure 6-66

5. Place the cylinder head on the workbench with the combustion side down. Install the valve spring **(Figure 6-66, (3))** and spring retainer **(Figure 6-66, (2))**.

6. Using the valve spring compressor tool, compress the valve spring.

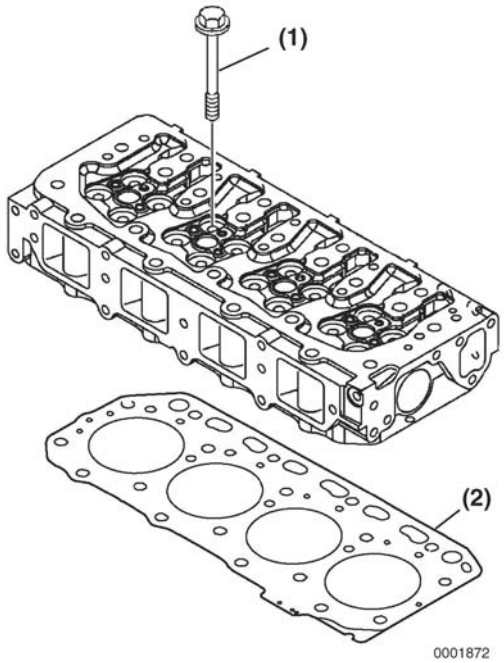
7. Insert the valve keepers **(Figure 6-66, (1))** and slowly release the tension in the valve spring. Repeat the steps on all the remaining valves.

Reassembly of Cylinder Head

1. Carefully clean both the combustion surface of the cylinder head and the top surface of the cylinder block. Then place a new cylinder head gasket **(Figure 6-67, (2))** on the cylinder block.

2. Position the cylinder head on the on the cylinder head gasket.

4TNV98 Engine



4TNE98 Engine

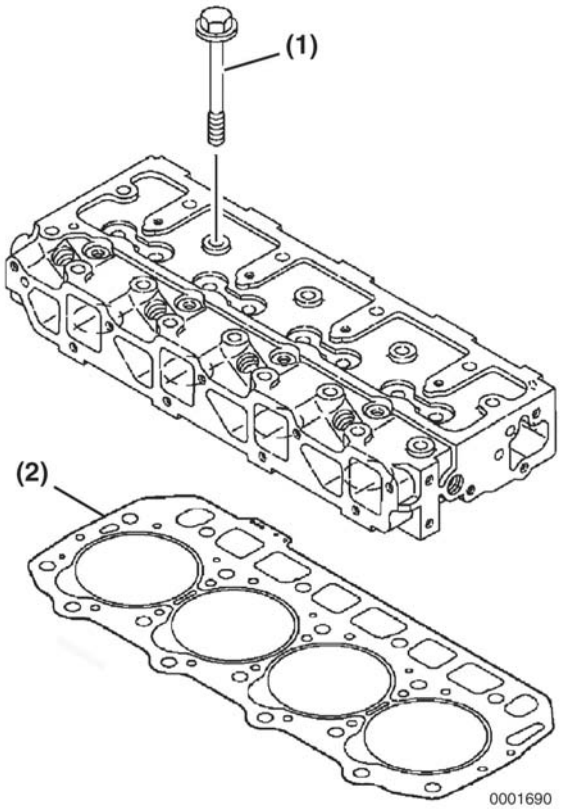


Figure 6-67

3. Lightly oil the threads of the cylinder head bolts **(Figure 6-67, (1))**. Tighten the bolts to the specified torque in two steps as shown in the chart below. Tighten in the sequence shown in **(Figure 6-68)**. See Special Torque Chart on page 73 for specification.

First Step	1/2 of final torque
Second Step	Final torque

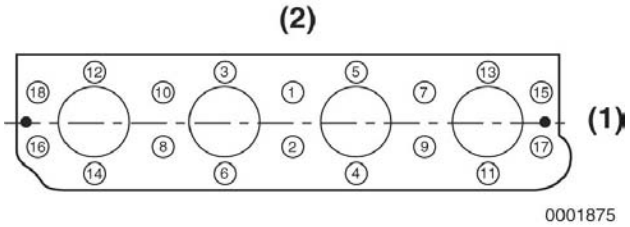


Figure 6-68

1) Fan End
2) Camshaft Side

Reassembly of Rocker Arm Assembly

4TNV98 Engine

1. Reinstall the valve bridges **(Figure 6-69, (3))** in their original locations and ensure each seat **(Figure 6-69, (4))** is in place.

2. Insert the push **rods (Figure 6-69, (2))** in their original locations.

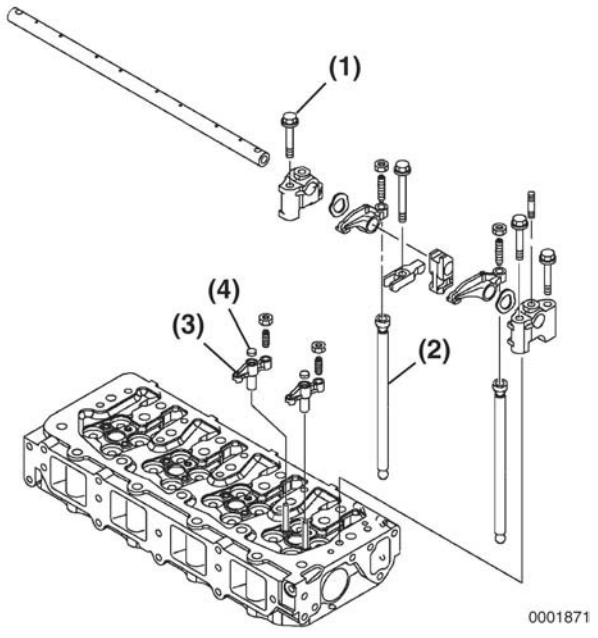


Figure 6-69

IMPORTANT
The wave washers **(Figure 6-70, (2))** must be installed with the bow facing the rocker arms **(Figure 6-70, (1)).**

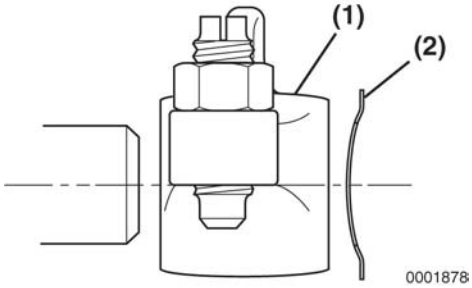


Figure 6-70

IMPORTANT
Ensure the lubrication holes **(Figure 6-71, (1))** in the rocker arm shaft are oriented correctly with respect to the rocker arms **(Figure 6-71, (2)).**

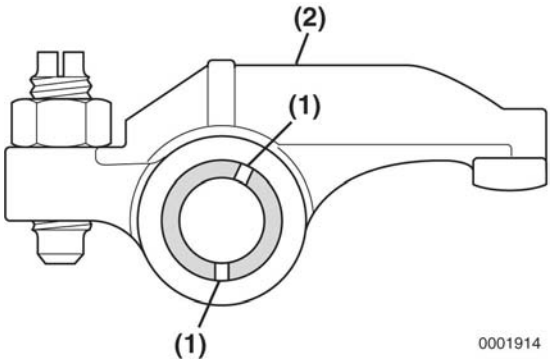


Figure 6-71

3. Lubricate the rocker arm shaft. Slide the rocker arm supports **(Figure 6-72, (6))**, wave washers **(Figure 6-72, (7))**, rocker arms **(Figure 6-72, (8))**, and fuel injector retainers **(Figure 6-72, (4))** onto the shaft.

NOTE : To properly align the rocker arm shaft with the rocker arm shaft supports, first reinstall one of the end rocker arm supports **(Figure 6-72, (6))** with a hole for the shaft alignment stud **(Figure 6-72, (5))**. Align the hole in the rocker arm shaft and the hole in the rocker arm support bracket. Reinstall the alignment stud.

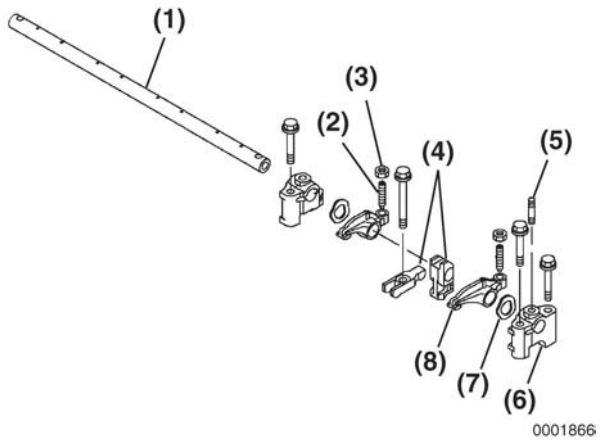


Figure 6-72

NOTE : **Figure 6-72** shows components for one cylinder. Components for all remaining cylinders are assembled in the same order.

4. Position the rocker arm assembly on a flat surface. Reinstall the alignment studs **(Figure 6-72, (5))**.

5. Place the rocker arm shaft assembly onto the cylinder head.

6. If removed, reinstall the valve adjusting screws **(Figure 6-72, (2))** and lock nuts **(Figure 6-72, (3))**.

7. Align the push rods with their respective rocker arms.

8. Reinstall and tighten the rocker arm shaft retaining bolts to the specified torque.

9. Tighten the rocker arm shaft alignment studs.

10. Adjust the valve clearance.

11. Reinstall the fuel injectors. See Installation of the Fuel Injectors on page 167.

4TNE98 Engine

1. Lubricate the rocker arm shaft. Slide the rocker arm support brackets **(Figure 6-30, (4)),** springs **(Figure 6-30, (5))** and rocker arms **(Figure 6-30, (6))** onto the shaft.

NOTE : The rocker arm shaft fits tightly in the rocker arm support brackets. Clamp the support bracket in a padded vise and twist the rocker arm shaft to remove. Reverse this process when you reinstall the rocker arm shaft into the support brackets.

NOTE : To properly align the rocker arm shaft with the rocker arm shaft supports, first install the rocker arm support bracket **(Figure 6-31, (4))** with the hole for the shaft alignment screw **(Figure 6-31, (1))**. Align the hole in the rocker arm shaft and the hole in the rocker arm support bracket. Install the alignment screw.

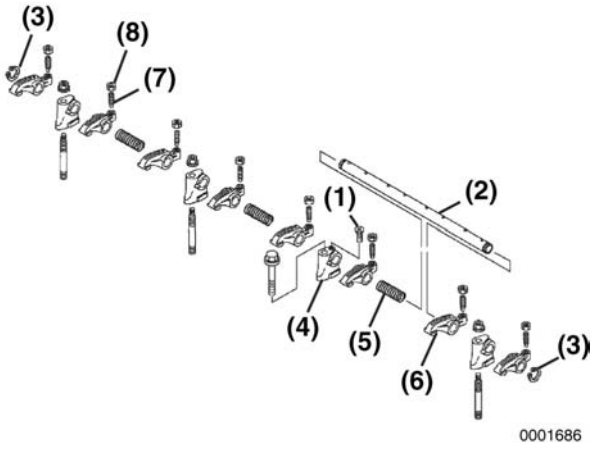


Figure 6-31

2. Position the rocker arm assembly on a flat surface. Install the retaining rings **(Figure 6-31, (3))** onto the end of the rocker arm shaft.

3. Install and hand tighten the rocker arm shaft retaining bolt and nuts.

4. Install the valve adjusting screws **(Figure 6-31, (7))** and lock nuts **(Figure 6-31, (8))**.

5. Place the rocker arm assembly in place onto the cylinder head. Tighten the rocker arm support bracket nuts and bolt to the specified torque. Tighten the rocker arm shaft alignment screw.

6. Align the push rods with their respective rocker arms and adjust the valve lash. *(See Measuring and Adjusting Valve Clearanceon page 104.)*

Reassembly of the Valve Cover

1. Lightly grease a new valve cover gasket **(Figure 6-73, (6))**. Place the gasket in the groove of the valve cover **(Figure 6-73, (3))**.

2. Place the valve cover on the cylinder head.

3. Be sure new O-rings **(Figure 6-73, (5))** are installed on the valve cover nuts. Reinstall and tighten the valve cover nuts **(Figure 6-73, (4))**.

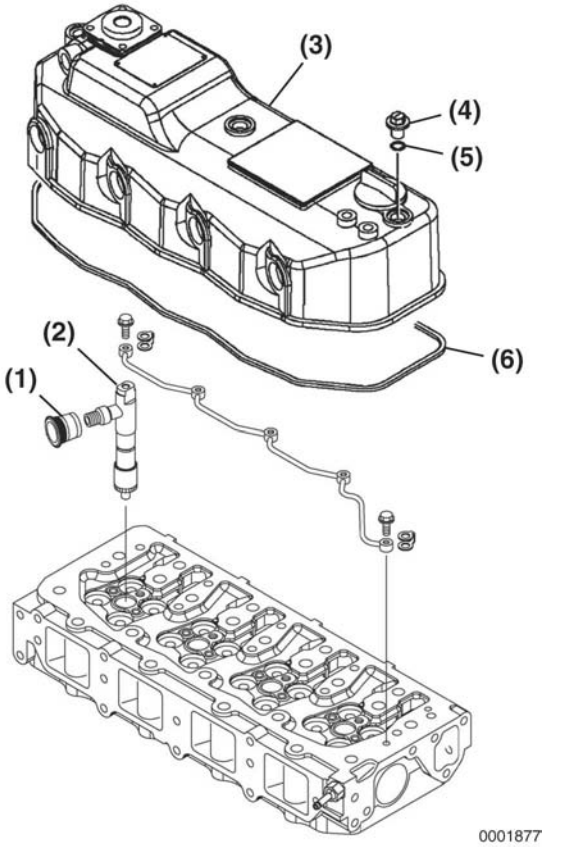


Figure 6-73

4. Reinstall the fuel injector grommets **(Figure 6-73, (1))**.

5. Reinstall the exhaust manifold using a new gasket. Tighten the bolts to specification.

6. Reinstall the intake manifold using a new gasket. Tighten the bolts to specification.

7. Reconnect the fuel injector return hose and fuel injection pump coolant hoses.

8. Reinstall the high-pressure fuel line grommets into the valve cover.

9. Reinstall the high pressure and fuel return lines. See Installation of the Fuel Injectors on page 167.

10. Reinstall the coolant pump. See Reassembly of Engine Coolant Pump on page 208.

11. Reinstall the alternator.

12. Reconnect the turbocharger oil supply and drain lines.

13. Reconnect the air intake hose.

Assembly of Glow Plugs

4TNE98 Engine Only

1. Install the glow plugs **(Figure 6-33, (1))** into the cylinder head **(Figure 6-33, (4))**. Torque the glow plugs to the specified torque.

2. Connect the glow plug harness **(Figure 6-33, (3))** to the glow plugs.

3. Install the glow plug cover **(Figure 6-33, (2))** on each glow plug.

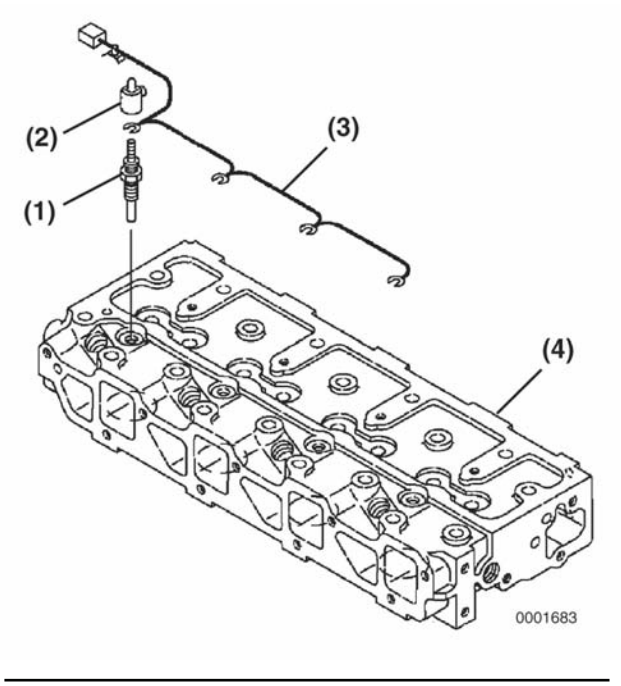


Figure 6-33

Measuring and Adjusting Valve Clearance

Measure and adjust while the engine is cold.

NOTES

- The No. 1 piston position is on the flywheel end of the engine, opposite the radiator. The firing order is 1-3-4-2 for 4-cylinder engines.
- 4-cylinder engines fire every 180° of crankshaft rotation.
- Valve clearance of both the intake and exhaust valves can be checked with the piston for that cylinder at top dead center (TDC) of the compression stroke. When a piston is at TDC of the compression stroke, both rocker arms will be loose and the cylinder TDC mark on the flywheel will be visible in the timing port of the flywheel housing.
- If there is no valve clearance, and the cylinder is at TDC of the compression stroke, extreme wear, or damage to the cylinder head or valves may be possible.
- If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top dead center after turning. Make adjustment for the remaining cylinders in the order of firing by turning the crankshaft each time.
- To decrease the number of rotations required to check all cylinders, other cylinders can also be checked as indicated in the chart below.

4-Cylinder Engines

Cylinder No.	1		2		3		4	
Valve	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
No. 1 Cylinder at TDC Compression	•	•	•			•		
No. 4 Cylinder at TDC Compression				•	•		•	•

4TNE98 Engine

1. Remove the valve cover. *See Removal of Valve Cover on page 103*.

NOTE : If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top dead center after turning, and make adjustment for other cylinders in the order of firing by turning the crankshaft.

4TNV98 Engine

The 4-valve cylinder head operates two valves with a single rocker arm by employing a valve bridge **(Figure 6-77, (1))** between the two valves **(Figure 6-77, (2))**. Clearance **(Figure 6-77, (4))** between the valve bridge and valves must be set before adjusting the clearance **(Figure 6-77, (5))** between the rocker arm **(Figure 6-77, (3))** and valve bridge.

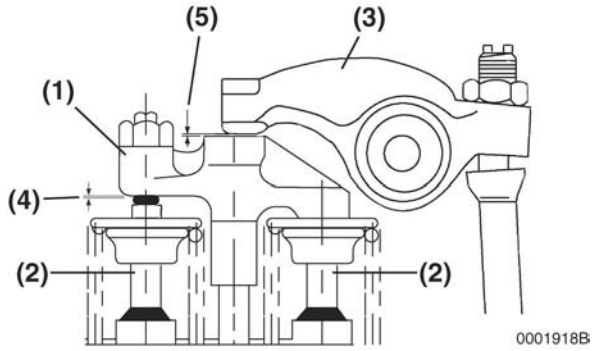


Figure 6-77

1. Remove the valve cover. See Removal of Valve Cover on page 103.

NOTE : If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top dead center after turning, and make adjustment for other cylinders in the order of firing by turning the crankshaft 180° each time.

2. Rotate the crankshaft clockwise as seen from the coolant pump end, to bring No. 1 piston to TDC on the compression stroke while watching the rocker arm motion and the timing grid on the flywheel. (Position where both the intake and exhaust valves are closed.)

3. Make sure there is clearance **(Figure 6-77, (5))** between the valve bridge **(Figure 6-77, (1))** and the rocker arm **(Figure 6-77, (3))**.

IMPORTANT

Do not loosen or tighten the valve adjusting screw lock nut without holding the valve bridge. Always hold the valve bridge using a wrench to prevent bending of the valve stems.

4. Loosen the valve bridge adjusting screw lock nut **(Figure 6-78, (1))** while holding the bridge **(Figure 6-78, (3))** with a wrench **(Figure 6-78, (2))**.

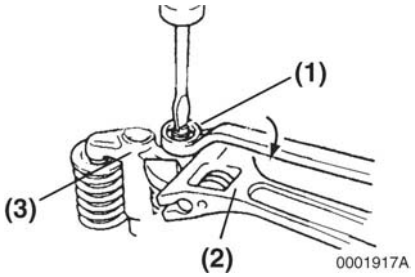


Figure 6-78

5. To assure the valve bridge contacts the rear valve, apply light, downward **(Figure 6-79, (4))** finger pressure on the valve bridge **(Figure 6-79, (3)**, and loosen the valve bridge adjusting screw **(Figure 6-79, (1))**, until there is visible clearance **(Figure 6-81, (2))** between the adjusting screw and the front valve.

6. To assure the valve bridge has equal contact with the front and rear valves, apply light downward **(Figure6-79,(4))** pressure on the valve bridge **(Figure6-79,(3))**, adjust the valve bridge adjusting screw **(Figure 6-79,(1)), (Figure 6-81,(1))** so there is zero “0”clearance **(Figure 6-81,(2))** between the adjusting screw and the front valve.

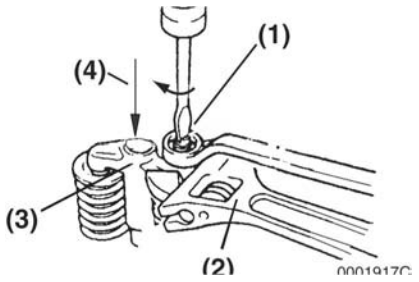


Figure 6-79

7. Tighten the lock nut **(Figure 6-80, (1))**, while holding the valve bridge **(Figure 6-80, (3))** with a wrench **(Figure 6-80, (2))**. Verify that the valve clearance **(Figure 6-81, (2)** is zero “0”.

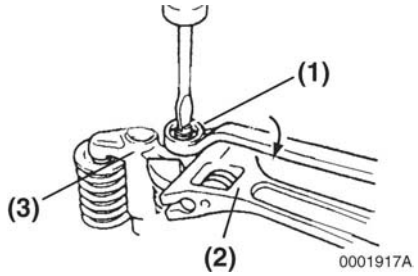


Figure 6-80

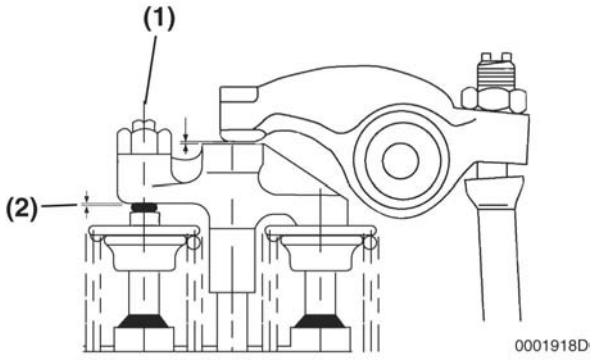


Figure 6-81

NOTE : There is a tendency for the clearance to decrease slightly when the lock nut is tightened. It is suggested that you make the initial clearance adjustment is made slightly on the “loose” side before tightening the lock nut.

8. To adjust the actual valve clearance between the rocker arm and the valve bridge, insert a feeler gauge **(Figure 6-82, (1))** of the correct thickness (See Adjustment Specifications on page6-6) between the rocker arm **(Figure 6-82, (2))** and valve bridge **(Figure 6-82, (3))**. Record the results and use this value as an indication of wear.

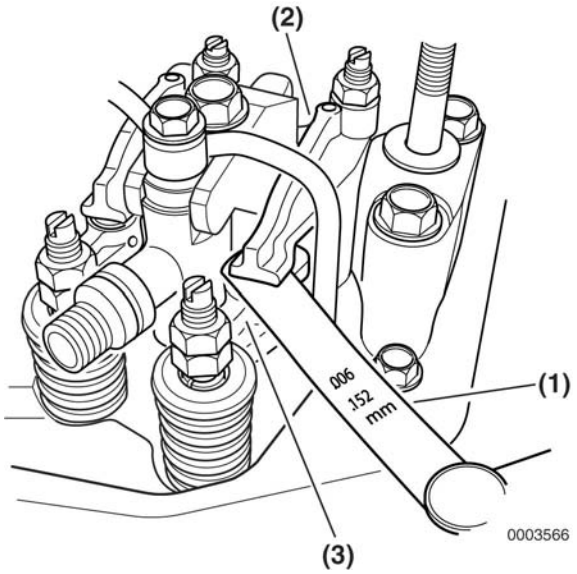


Figure 6-82

9. If adjustment is required, proceed to the next step.

10. Loosen the valve adjusting screw lock nut **(Figure 6-83, (5))** and valve adjusting screw **(Figure 6-83, (4))** on the rocker arm **(Figure 6-83, (3))** and check the clearance gap **(Figure 6-83, (2))** for evidence of dirt or wear.

NOTE : There is a tendency for the clearance to decrease slightly when the lock nut is tightened. It is suggested that you make the clearance adjustment is made slightly on the “loose” side before tightening the lock nut.

11. Adjust the valve clearance **(Figure 6-83, (2))** by turning the adjusting screw **(Figure 6-83, (4))** until there is a slight “drag” on the feeler gauge when sliding it between the rocker arm and the valve bridge.

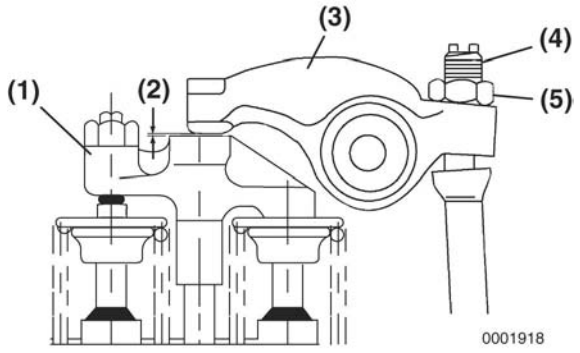


Figure 6-83

12. Hold the adjusting screw **(Figure 6-83, (4))** while tightening the valve adjusting screw lock nut **(Figure 6-83, (5)).** Recheck the clearance.

13. Apply oil to the contact surface between the adjusting screw and push rod.

14. Rotate the crankshaft to measure and adjust the set of valves. Continue until all valves are measured and adjusted.

Crankshaft and Camshaft Components

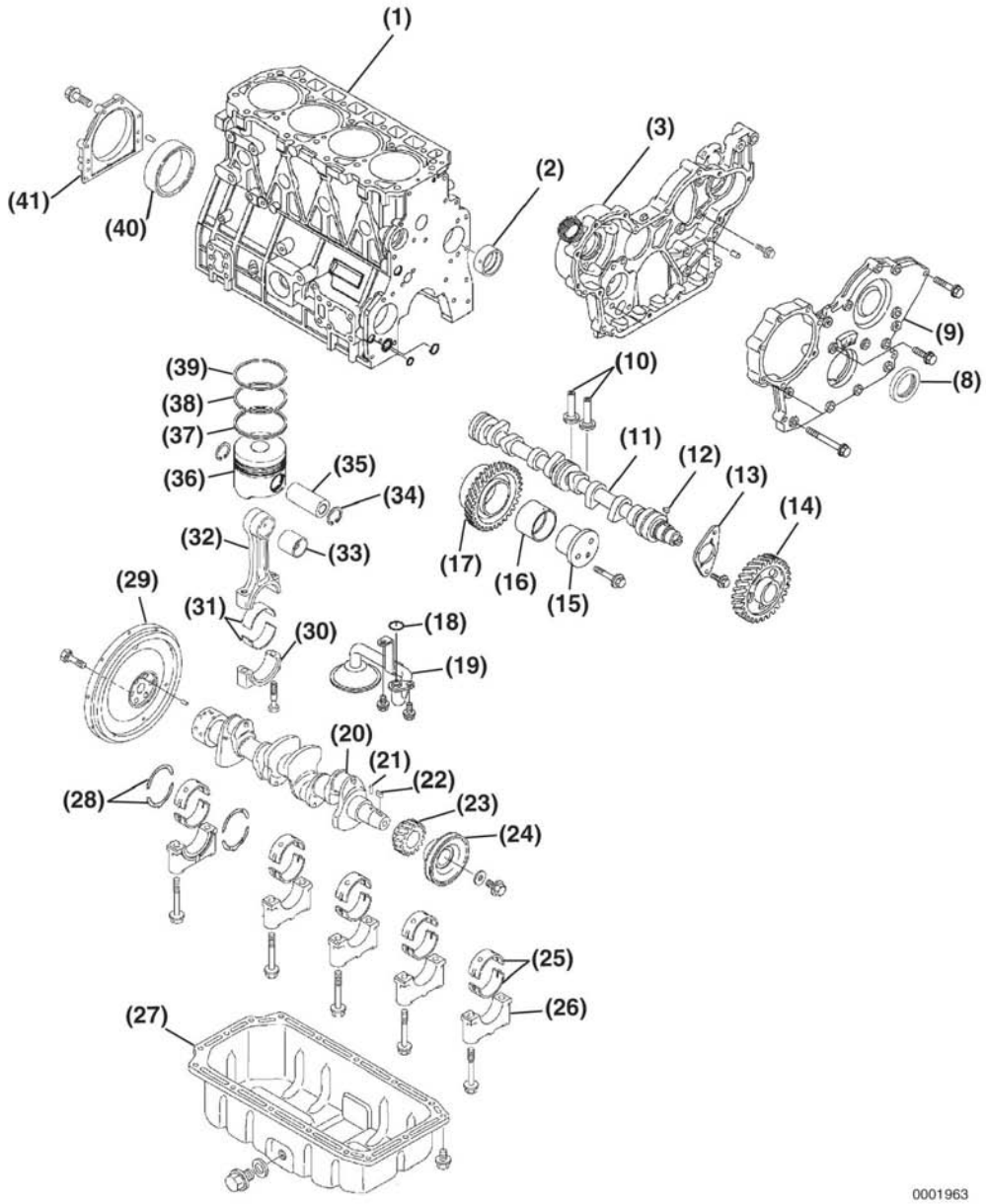


Figure 6-84

(1) Cylinder Block.
(2) Camshaft Bushing.
(3) Gear Case
(8) Front Crankshaft Seal.
(9) Gear Case Cover
(10) Tappets.
(11) Camshaft.
(12) Camshaft Gear Key.
(13) Camshaft End Plate.
(14) Camshaft Gear.
(15) Idler Gear Shaft.
(16) Idler Gear Bushing.
(17) Idler Gear.
(18) Oil Pickup O-Ring.
(19) Oil Pickup.
(20) Crankshaft.
(21) Parallel Pin.
(22) Crankshaft Gear Key.
(23) Crankshaft Gear.
(24) Crankshaft Pulley.
(25) Main Bearing Inserts.
(26) Main Bearing Cap.
(27) Oil Pan.
(28) Thrust Bearings.
(29) Flywheel.
(30) Connecting Rod Cap.
(31) Connecting Rod Bearing Inserts.
(32) Connecting Rod.
(33) Wrist Pin Bushing.
(34) Circlip .
(35) Wrist Pin.
(36) Piston.
(37) Oil Ring.
(38) Second Compression Ring.
(39) Top Compression Ring.
(40) Crankshaft Rear Seal.
(41) Crankshaft Rear Seal Housing.

Disassembly of Engine

Prepare a clean, flat working surface on a workbench large enough to accommodate the engine components. Discard all used gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of engine.

CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

If the engine will be completely disassembled, the following preliminary steps should be performed:

1. Disconnect the battery cables at the battery. Always disconnect the negative (-) cable first.

2. Remove the throttle cable, electrical connections, intake and exhaust system connections, and fuel supply lines from the engine.

3. Remove the alternator.

4. Drain the engine coolant from the radiator and cylinder block. See Drain, Flush and Refill Cooling System With New Coolant on page 159. Remove the cooling system components from the engine.

5. Remove the engine from the machine. Mount the engine to a suitable engine repair stand having adequate weight capacity.

⚠ CAUTION

Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.

6. Clean the engine by washing with solvent, air or steam cleaning. Carefully operate so as to prevent any foreign matter or fluids from entering the engine or any fuel system or electrical components remaining on the engine.

7. Drain the engine oil into a suitable container. Remove the oil filter.

8. Remove the cylinder head. See 4-Valve Cylinder Head on page 80.

9. Remove the fuel injection pump from the gear case / front plate only if it must be sent out for repair, or will interfere with other procedures such as “hot tank” cleaning. If the fuel injection pump does not need to be repaired, leaving it mounted to the timing gear case or plate will eliminate the need to re-time it during reassembly. See Fuel Injection Pump on page 141.

10. Remove the starter motor. See Removal of Starter Motor on page 225.

Disassembly of Camshaft and Timing Components

Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of the camshaft and timing components.

Removal of Timing Gear Case Cover

1. Remove the bolt and washer retaining the crankshaft pulley.

IMPORTANT

Use care not to damage the threads in the end of the crankshaft when removing the crankshaft pulley.

2. Remove the crankshaft pulley using a gear puller.

3. Remove the bolts that retain the gear case cover to the cylinder block and oil pan.

4. Remove the gear case cover **(Figure 6-85, (1))**.

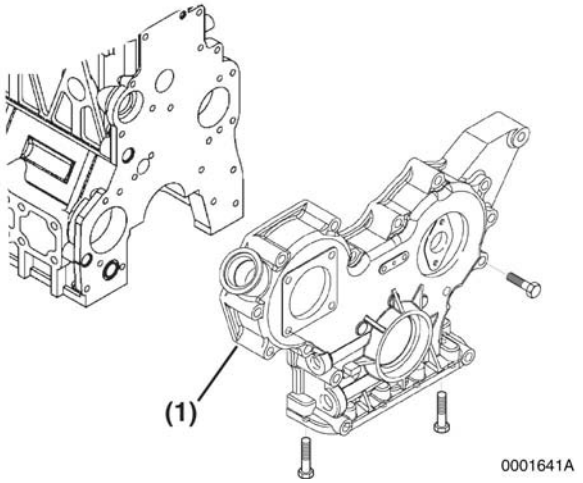


Figure 6-85

Checking Timing Gear Backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of mating gears **(Figure 6-86)**. If not within specification, replace both mating gears. See Timing Gear Backlash on page 69 for service limits.

NOTE: Do not allow the gear being checked to move axially as excess end play could cause a false reading.

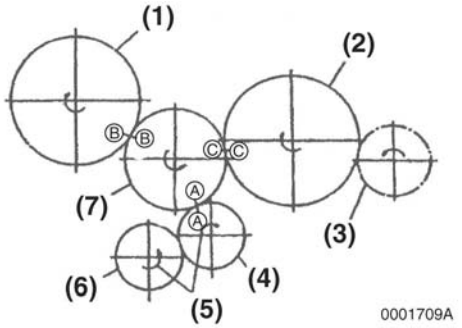


Figure 6-86

(1) Fuel Injection Pump Drive Gear.
(2) Camshaft Drive Gear.
(3) Auxiliary Drive Gear (Optional).
(4) Crankshaft Drive Gear.
(5) Direction of Rotation.
(6) Oil Pump Drive Gear (4TNV94L - 4TNV106).
(7) Idler Gear.

Measuring Idler Gear-to-Crankshaft Gear Backlash

1. Install a dial indicator as shown in **Figure 6-87**.

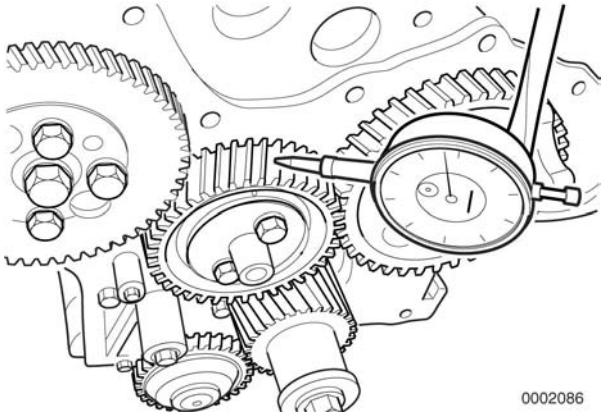


Figure 6-87

2. Rotate the idler gear back and forth to check the idler gear-to-crankshaft gear backlash. The total indicator reading is the backlash. Record the measurement.

Measuring Idler Gear-to-Camshaft Gear Backlash

1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.

2. Install the dial indicator to read the camshaft gear backlash. Rotate the camshaft drive gear against the idler gear to measure the backlash. Record the measurement.

3. Check the idler gear-to-fuel injection pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

Removal of Timing Gears

1. Remove the bolts from the idler gear shaft **(Figure 6-88, (1))**. Remove the idler gear shaft, idler gear **(Figure 6-88, (2))** and bushing **(Figure 6-88, (3))**.

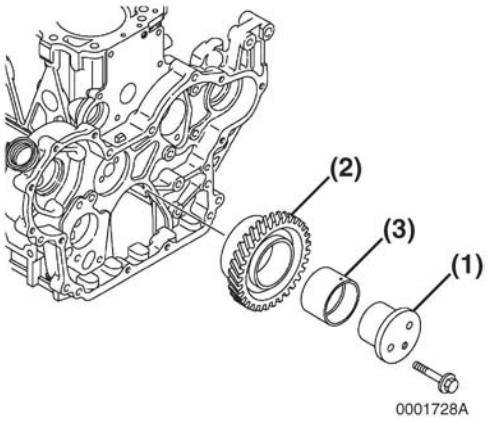


Figure 6-88

2. Do not remove the crankshaft gear unless it is damaged and requires replacement. If the gear must be removed, remove it using a gear puller.

3. Removal of the camshaft gear requires the camshaft be removed and placed in a press. Do not remove the camshaft gear unless it or the camshaft is damaged and requires replacement. See Removal of Camshaft on page 114.

CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.

4. Do not remove the fuel injection pump drive gear unless absolutely necessary to avoid damage to the gear or pump. Do not loosen or remove the four bolts (Figure 115, (3)) retaining the pump drive gear to the hub. Only remove the nut (Figure 6-89, (1)) and washer (Figure 115, (2)), leaving the hub attached to the gear. Remove the pump drive gear and hub as an assembly using a gear puller.

4TNV98 Engine

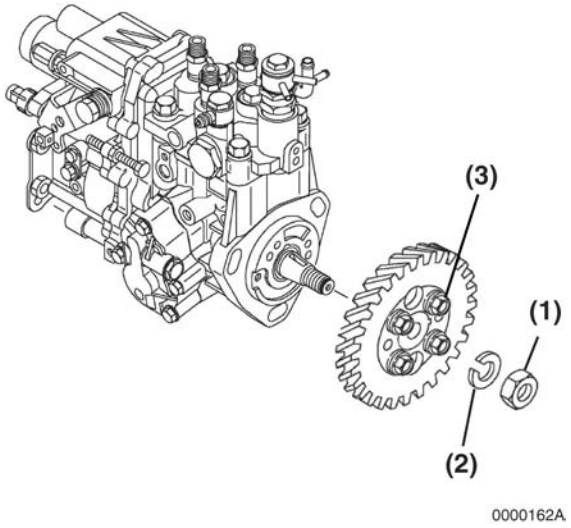


Figure 6-89

Removal of Oil Pan

1. Invert the engine (oil pan up) on the engine stand.

2. Remove the oil pan (Figure 116, (1)).

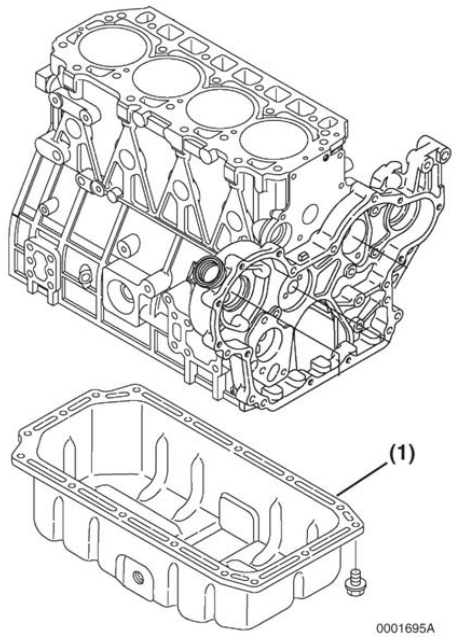


Figure 6-90

3. Remove the oil pickup tube **(Figure 6-91, (1))** and O-ring **(Figure 6-91, (2))**.

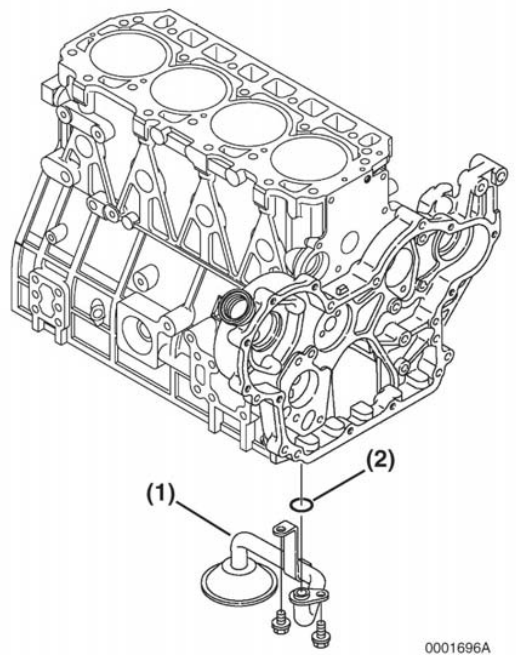


Figure 6-91

Removal of Camshaft

1. Before removing the camshaft, check the camshaft end play.

- **Method A** : Install a dial indicator **(Figure 6-92, (1))** on the cylinder block. Move the camshaft **(Figure 6-92, (2))** back and forth to measure the end play. Record the measurement. See Camshaft on page 68 for the service limit.

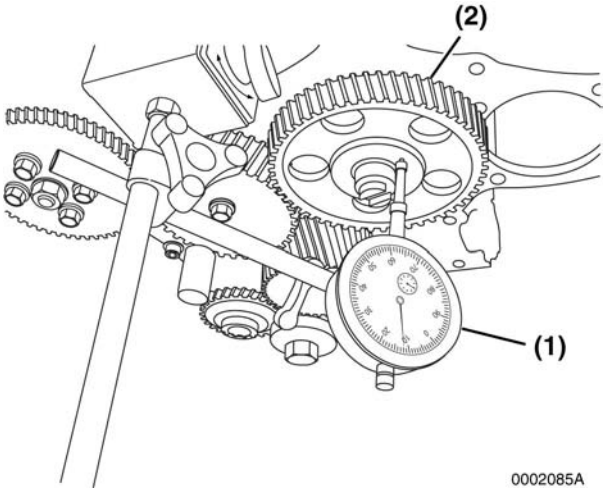


Figure 6-92

- **Method B** : Use a feeler gauge to measure the clearance between the thrust plate **(Figure 6-93, (1))** and front camshaft bearing **(Figure 6-93, (2))**. See Thrust Bearing on page 70 for the service limit.

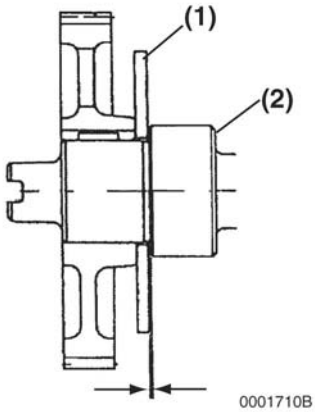


Figure 6-93

2. Remove the two bolts **(Figure 6-94, (3))** retaining the camshaft thrust plate **(Figure 6-94, (1))**.

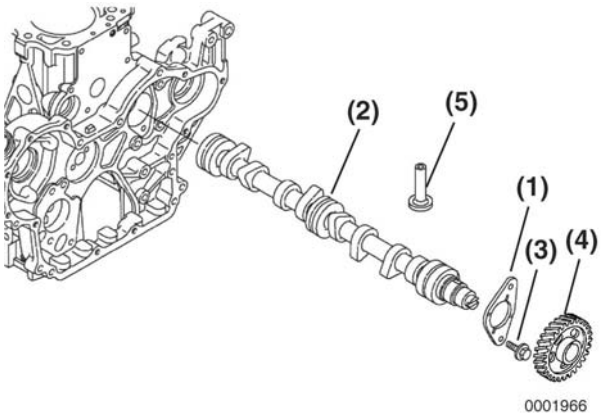


Figure 6-94

3. Rotate the engine in the engine stand so that gravity causes the tappets **(Figure 6-94, (5))** to drop away from the camshaft lobes.

NOTE : Rotate the camshaft at least two turns to "bump" any sticking tappets away from the camshaft.

4. Slowly pull the camshaft **(Figure 6-94, (2))** assembly out of the engine being careful not to damage the front camshaft bushing.

NOTE : If the engine is not installed on an engine repair fixture, stand the engine upright on the flywheel end mounting flange. Rotate the camshaft at least two turns to bump the tappets out of the way to prevent the tappets from interfering with the removal of the camshaft.

NOTE : The tappets are "mushroom" shaped and must be removed from inside the engine crankcase.

5. Remove the tappets. Mark the tappets so they can be reinstalled in the same location.

6. Remove the camshaft drive gear **(Figure 6-94, (4))** only if the gear or camshaft require replacement. Use a knife-edge puller and a press to remove the gear. The gear is a shrink-fit and will need to be heated to 356° - 392°F (180° - 200°C) to remove.

Removal of Gear Case or Front Plate

NOTE : The camshaft must be removed before the gear case / front plate can be removed. See Inspection of Camshaft on page 125.

1. Remove the oil pump.

NOTE : It is not necessary to remove the fuel injection pump from the gear case / front plate to remove the gear case / front plate. If the fuel injection pump does not need to be repaired, leaving it mounted to the timing gear case / front plate will eliminate the need to re-time it during assembly. See Fuel Injection Pump on page 141.

2. Remove the bolts **(Figure 6-95, (4))**.

3. Remove the gear case **(Figure 6-95, (1))** or front plate from the cylinder block. Thoroughly clean all old sealant from the mating surfaces.

4. Inspect and measure the camshaft bushing. See Camshaft on page 68 for the service limit. If damaged or worn beyond service limits, remove the camshaft bushing **(Figure 6-95, (3))**.

5. Remove two O-rings **(Figure 6-95, (2))**.

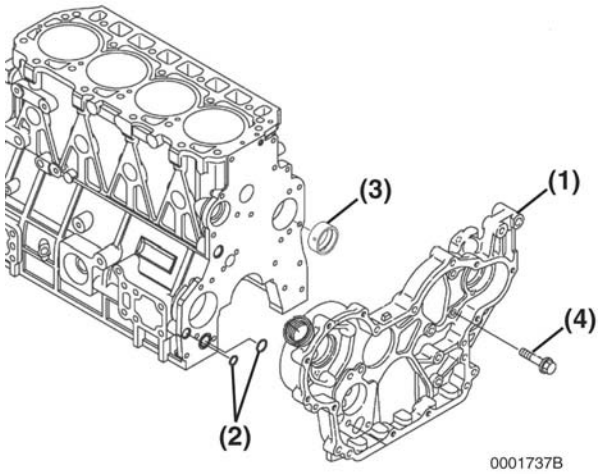


Figure 6-95

Disassembly of Crankshaft and Piston Components

Removal of Pistons

CAUTION

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.

IMPORTANT

Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

NOTE : Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Using a feeler gauge, measure the connecting rod side clearance as shown **(Figure 6-97)**. See Connecting Rod on page 72 for the standard limit. If the measurement is out of specification, replace the crankshaft, connecting rod, or both.

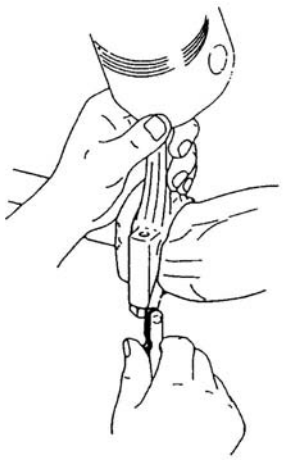


Figure 6-97

2. Measure bearing oil clearance prior to removing the pistons and connecting rods to determine extent of wear. Record the measurements.

IMPORTANT

Mark the connecting rod caps and connecting rods so the caps and connecting rods stay together.

(a) Remove the bearing cap. Do not remove the bearing inserts at this time.

(b) Wipe oil from the bearing insert and crankshaft journal surfaces.

(c) Place a piece of PLASTIGAGE® **(Figure 6-98, (1))** along the full width of the bearing insert.

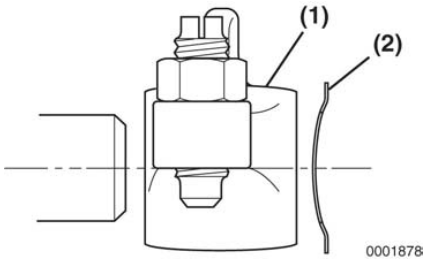


Figure 6-98

IMPORTANT

Do not rotate the crankshaft when using PLASTIGAGE. A false reading may result.

(d) Reinstall bearing cap and tighten to specification. See Special Torque Chart on page 73.

(e) Remove bearing cap.

(f) Compare the width of the flattened PLASTIGAGE to the graduation marks on the package **(Figure 6-99, (1))**. The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance.

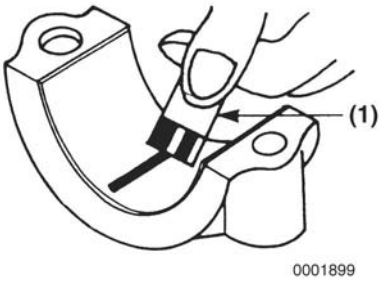


Figure 6-99

(g) Repeat with remaining connecting rods.

IMPORTANT

Do not allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

3. Use a wooden dowel against the connecting rod and tap the piston / connecting rod assembly out of the cylinder.

4. Mark the cylinder number on the piston and connecting rod.

5. Remove the bearing inserts **(Figure 6-100, (2))**.

6. Remove the compression rings **(Figure 6-100, (3))** from the piston using a piston ring expander.

7. Remove the oil ring **(Figure 6-100, (4))** from the piston using a piston ring expander.

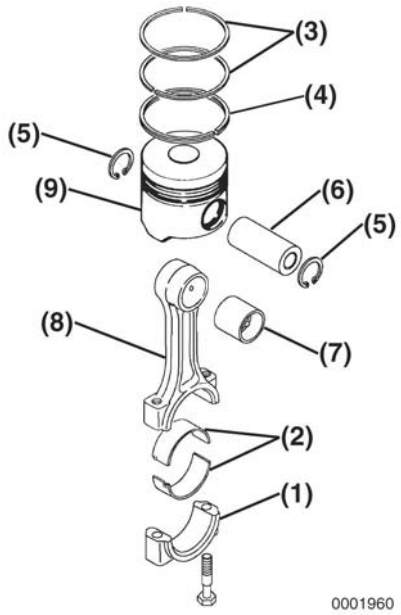


Figure 6-100

8. Remove the circlips **(Figure 6-100, (5))** from the wrist pin.

9. Remove the wrist pin **(Figure 6-100, (6))** and connecting rod **(Figure 6-100, (8))** from the piston **(Figure 6-100, (9))**.

10. Repeat the steps until all pistons are removed and dissembled.

Removal of Crankshaft

1. Remove the flywheel **(Figure 6-101, (1))** from the crankshaft.

2. Remove the bolts from the rear oil seal assembly **(Figure 6-101, (2-3))**. Remove the assembly from the engine.

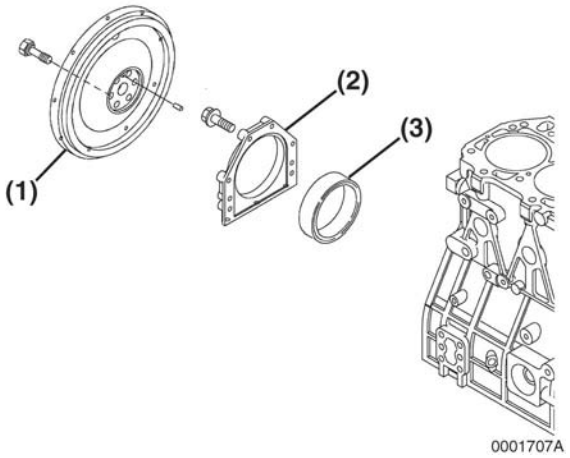


Figure 6-101

3. Before removing the main bearing caps, measure the crankshaft end play. Use either of the following two methods.

- **Method A** : Install a dial gauge **(Figure 6-102, (1))** on the cylinder block. Move the crankshaft **(Figure 6-102, (2))** in and out to measure the end play. Record the measurement.

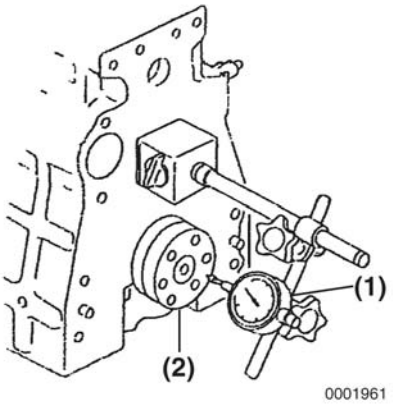


Figure 6-102

• **Method B** : Use a feeler gauge to measure the clearance **(Figure 6-103, (3))** between the thrust bearing **(Figure 6-103, (1))** and crankshaft **(Figure 6-103, (2))**. Record the measurement. See Thrust Bearing on page 70 for the service limit.

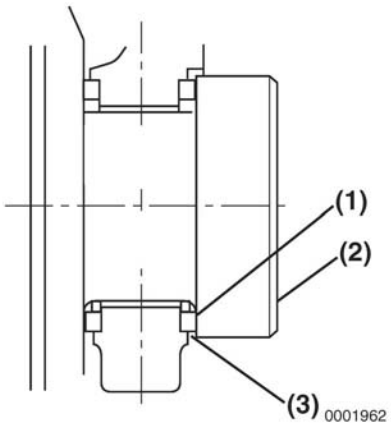


Figure 6-103

4. Remove the main bearing caps **(Figure 6-104, (3))**. Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same order as they were removed. Do not remove the bearing inserts at this time.

NOTE : The “arrows” on the main bearing caps point to the flywheel end of the engine.

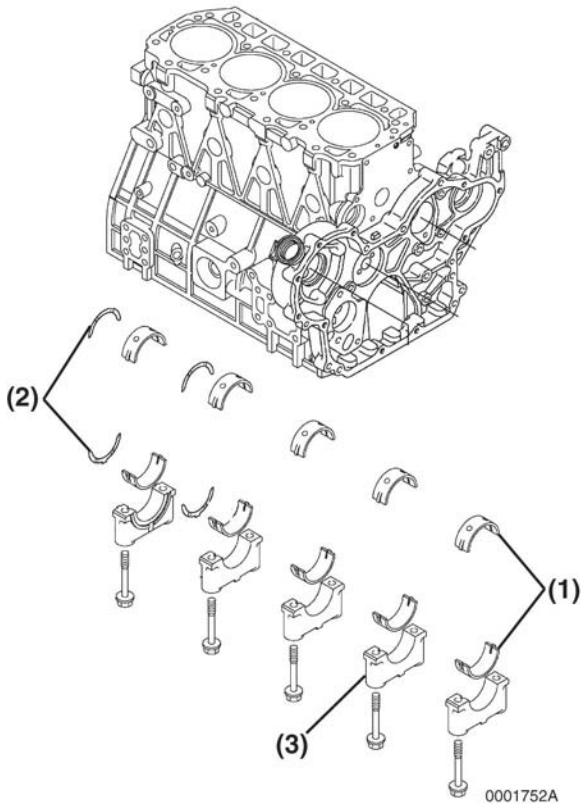


Figure 6-104

5. Measure bearing oil clearance prior to removing the crankshaft to determine extent of wear. Record the measurements.

(a) Wipe oil from the bearing insert and crankshaft journal surfaces.

(b) Place a piece of PLASTIGAGE **(Figure 6-105, (1))** along the full width of each bearing insert.

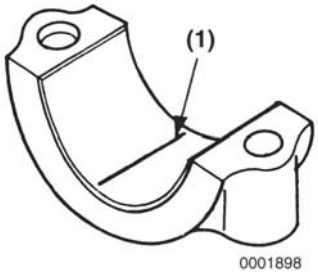


Figure 6-105

IMPORTANT

Do not rotate the crankshaft when using PLASTIGAGE. A false reading may result.

(c) Reinstall bearing caps and tighten to specification. See Special Torque Chart on page 69.

(d) Remove bearing caps.

(e) Compare the width of the flattened PLASTIGAGE to the graduation marks on the package **(Figure 6-106, (1))**. The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance.

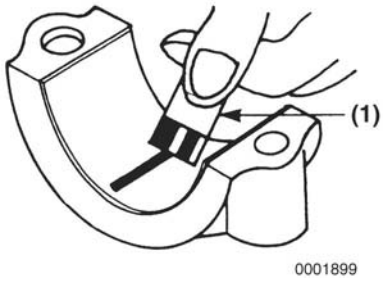


Figure 6-106

6. Remove the crankshaft from the engine.

7. Remove the bearing inserts **(Figure 6-104, (1))** and thrust bearings **(Figure 6-104, (2))**.

NOTE : Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

8. If necessary, remove the crankshaft gear **(Figure 6-107, (1))**, parallel pin **(Figure 6-107, (2))** and key **(Figure 6-107, (3))**.
If using a gear puller, be careful not to damage the threads in the end of the crankshaft.

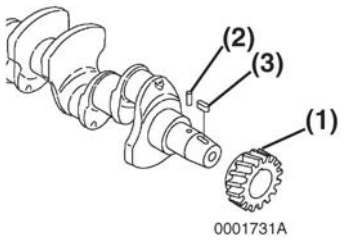


Figure 6-107

Inspection of Crankshaft and Camshaft Components

⚠ WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

Thoroughly clean all components using a brush and appropriate solvent. Each part must be free of carbon, gasket material, metal filings and other debris.

Replacement of Crankshaft Oil Seals

1. Remove the seal **(Figure 6-108, (2))** from the cover **(Figure 6-108, (1))**.

2. Apply a continuous bead of ThreeBond Liquid Gasket No. 1212 to the outside diameter of a new oil seal **(Figure 6-108, (2))**, and install in the gear case cover. Apply lithium grease to the lip of the seal.

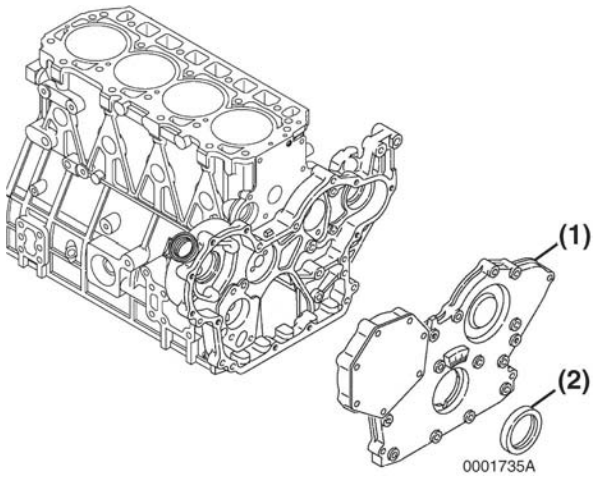


Figure 6-108

3. Remove the rear oil seal **(Figure 6-109, (3))** from the seal housing **(Figure 6-109, (2))**.

4. Apply a continuous bead of ThreeBond Liquid Gasket No. 1212 to the outside diameter of a new oil seal **(Figure 6-109, (2))**, and install in the housing. Apply lithium grease to the lip of the seal.

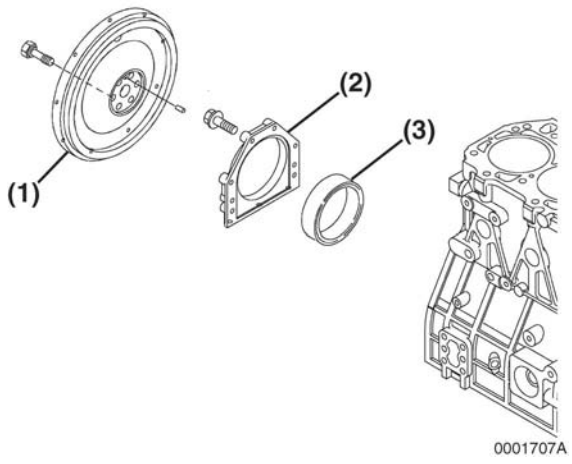


Figure 6-109

Measure Crankshaft Bearing Oil Clearance

Oil clearance should be checked during disassembly to determine the extent of wear, and during assembly to ensure long engine life. The same procedure is done for both connecting rods and main bearings.

Inspection of Cylinder Block

1. Ensure that oil passages are clear and unobstructed.

2. Check for discoloration or evidence of cracks. If a fracture is suspected, use the color check method or the Magnaflux method to determine if the cylinder block is fractured.

3. Inspect cylinders for roundness, taper, or evidence of scoring. Collect and record the measurements. Consider honing, reboring or replacing the cylinder block if the measurements are not within specification.

- Take measurements at three places **(Figure 6-110)** (a, b, c), and in two directions (d and e) in each cylinder.

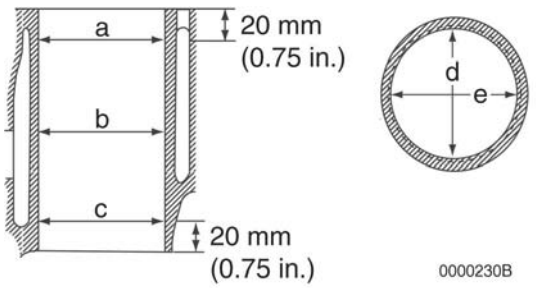


Figure 6-110

Inspection of Pistons, Piston Rings and Wrist Pin

NOTES

- On an engine with low hours, the pistons, piston rings may be reused if they are found to be within specifications. The pistons and piston rings must be reinstalled in the same cylinders from which they were originally removed.
- On an engine with high hours, the pistons rings should be replaced and the cylinder honed (See Honing and Boring on page 126) or replaced. The piston should be replaced as necessary.

1. Clean piston ring grooves using a piston ring groove cleaning tool. Follow manufacturer's instructions for correct operation.

2. Wash the pistons in an appropriate solvent using a soft brush.

3. Visually inspect each piston for cracks. Pay particular attention to the ring lands between the piston ring grooves.

4. Measure the diameter of the piston skirt at 90° to the wrist pin bore as shown **(Figure 6-111)**. Measurements must be taken at a specified distance **(Figure 6-111, (1))** from the bottom of the piston, based on engine model. Record the measurements. See Piston on page 71 for specifications.

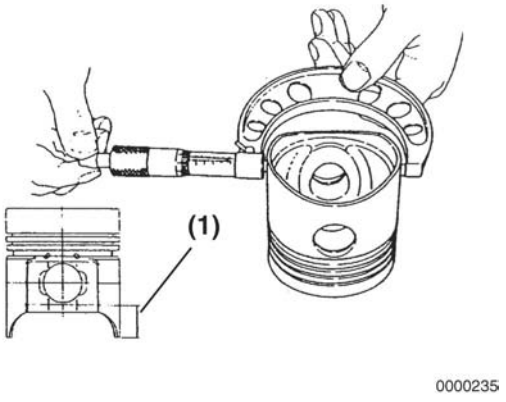


Figure 6-111

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection (see Inspection of Cylinder Block on page 109) to obtain piston-to-cylinder clearance. Record the measurements. See Piston on page 71 for specifications.

6. Measure the diameter of the wrist pin bore on both sides of the piston **(Figure 6-112)**. See Piston on page 71 for specifications. Record the measurements.

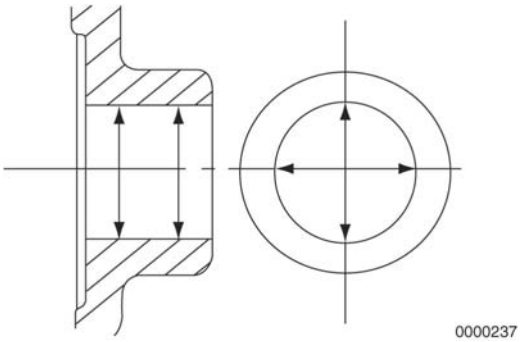


Figure 6-112

7. Measure the outside diameter of the wrist pin in three places and at 90° **(Figure 6-113)**. See Piston on page 71 for specifications. Record the measurements.

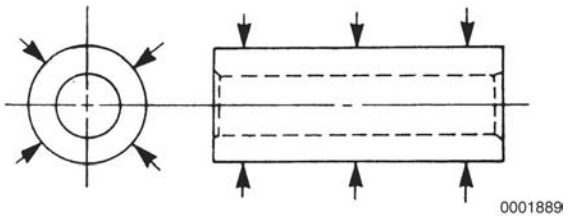


Figure 6-113

8. Using a micrometer, measure the thickness of each piston ring. See Piston on page 71 for specifications. Record the measurements.

NOTES

- On an engine with low hours, the pistons, piston rings and cylinders may be reused if they are found to be within specifications.
- On an engine with high hours, the pistons rings should be replaced and the cylinder honed (see Honing and Boring on page 126) or replaced. The piston should be replaced as necessary.

9. Place each compression piston ring in the groove as shown **(Figure 6-114)**. Use a feeler gauge to measure the clearance between the piston ring and the piston ring land. Record the measurements. See Piston Ring on page 71 for specifications. Replace the piston if not within specification.

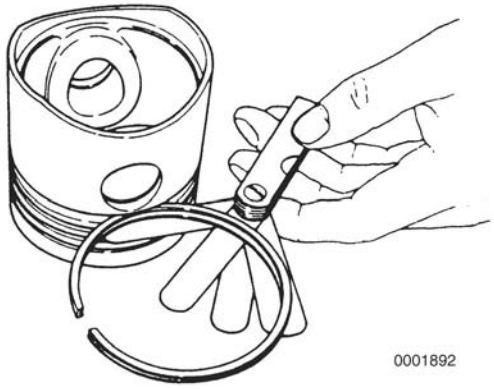


Figure 6-114

10. To measure piston ring end gap, insert each compression piston ring **(Figure 6-115, (1))**, one at a time, into the cylinder. Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 1.18 in. (30 mm) **(Figure 6-115, (2))** from the bottom of the bore. Remove the piston. Measure the end gap **(Figure 6-115, (3))** of each piston ring. Record the measurements. See Piston Ring on page 71 for specifications.

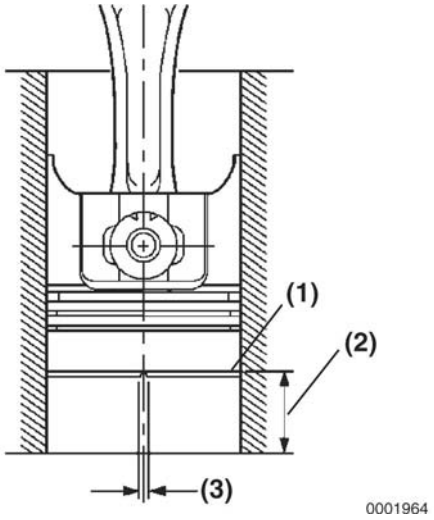


Figure 6-115

NOTE : Always check the piston ring end gap when installing new piston rings. See Piston Ring on page 71 for specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

11. Repeat the above steps for each cylinder and piston assembly.

Inspection of Connecting Rod

1. Measure the wrist pin bushing bore using a bore gauge **(Figure 6-116, (1))**. Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end **(Figure 6-116, (2))**. See Connecting Rod on page 72 for specifications.

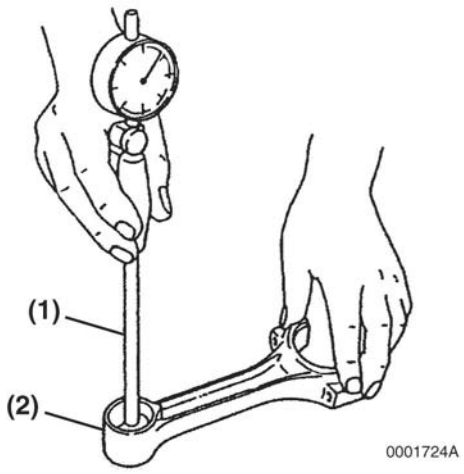


Figure 6-116

2. Place the connecting rod bearing inserts into the connecting rod and connecting rod cap. Install the rod cap and tighten the bolts to the specified torque.

3. Measure the inside diameter. See Crankshaft on page 70 for specifications.

Inspection of Tappets

1. Inspect the tappet contact surfaces for abnormal wear **(Figure 6-117, (1))**. Normal wear will be even as shown in **(Figure 6-117, (2))**. Slight surface defects can be corrected using an oilstone.

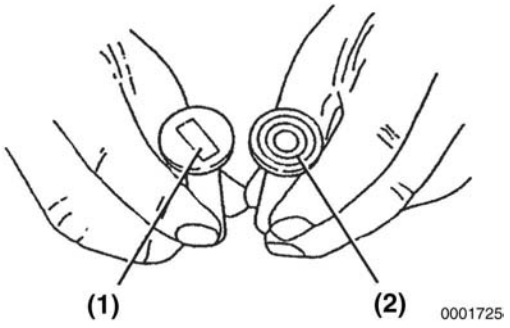


Figure 6-117

2. Measure the outside diameter of the tappet stem **(Figure 6-118, (1))**. See Tappet on page 72 for the service limit.

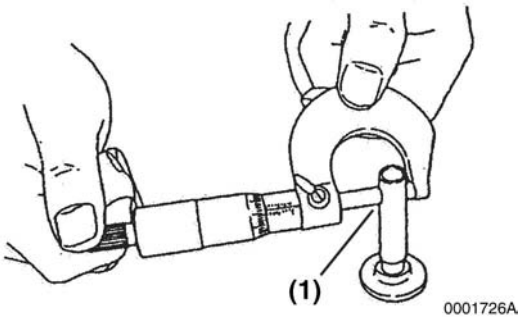


Figure 6-118

3. Measure the tappet bores in the cylinder block. See Tappet on page 72 for the service limit.

Inspection of Crankshaft

1. Place the crankshaft end journals **(Figure 6-119, (4))** on V-blocks.

2. Place a dial indicator **(Figure 6-119, (3))** on a center main bearing surface.

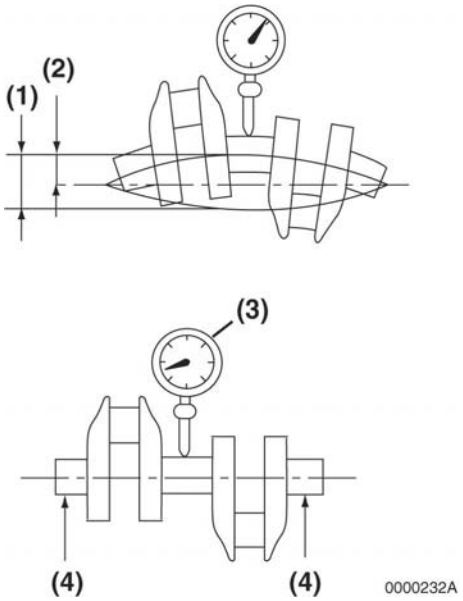


Figure 6-119

3. Rotate the crankshaft and observe runout. See Crankshaft on page 70 for specifications.

4. Use the color check method or Magnaflux® to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.

5. Measure the outside diameter of each crankpin **(Figure 6-120, (2))** and main bearing journal **(Figure 6-120, (1))**. See Crankshaft on page 70 for specifications. Take measurements at several places around each bearing surface. If not within specification, grind the journals and install undersize bearings, or replace the crankshaft.

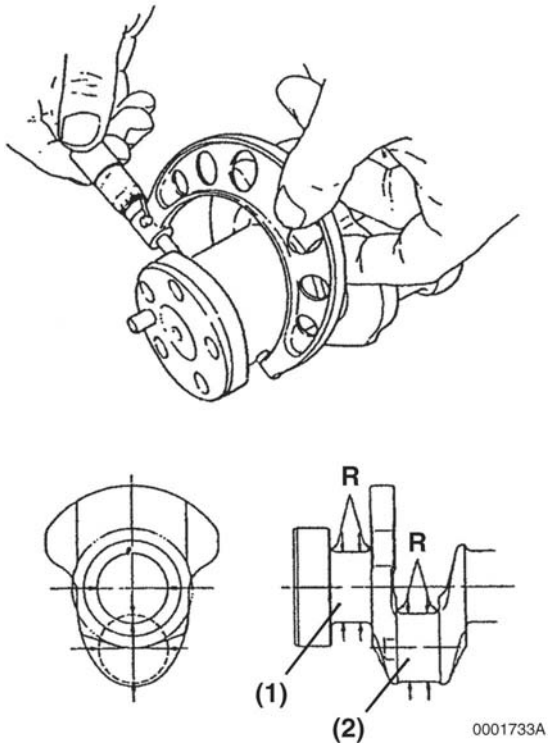


Figure 6-120

Inspection of Camshaft

1. Use V-blocks and a dial indicator to check camshaft bend **(Figure 6-121)**. Place the indicator on the center bearing journal.

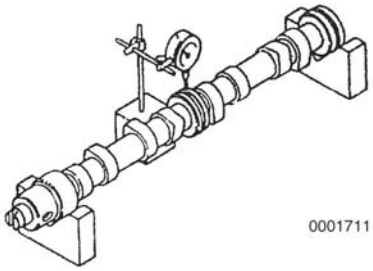


Figure 6-121

2. Rotate the camshaft and observe the runout. See Camshaft on page 68 for specifications.

3. Measure the height of each lobe **(Figure 6-122, (1))**. See Camshaft on page 68 for specifications.

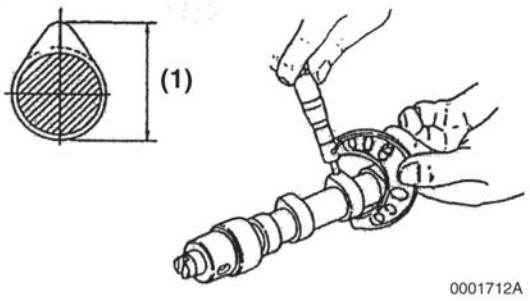


Figure 6-122

4. Measure the diameter of the gear end **(Figure 6-123, (1))**, intermediate **(Figure 6-123, (2))**, and flywheel end **(Figure 6-123, (3))** bearing journals. See Camshaft on page 68 for specifications.

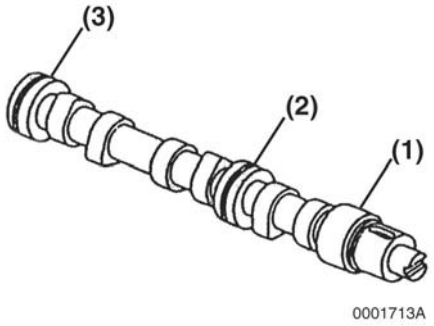


Figure 6-123

Inspection of Camshaft Bushing and Bores

1. Measure the I.D. of the front bushing and the remaining bores in the cylinder block. See Camshaft on page 68 for specifications.

2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no bearing inserts used.

Inspection of Idler Gear and Shaft

1. Measure the outside diameter **(Figure 6-124, (1))** of the idler gear shaft **(Figure 6-124, (2))**. See Idler Gear Shaft and Bushing on page 69 for specifications.

2. Measure the inside diameter **(Figure 6-124, (3))** of the idler gear bushing **(Figure 6-124, (4))**. See Idler Gear Shaft and Bushing on page 69 for specifications.

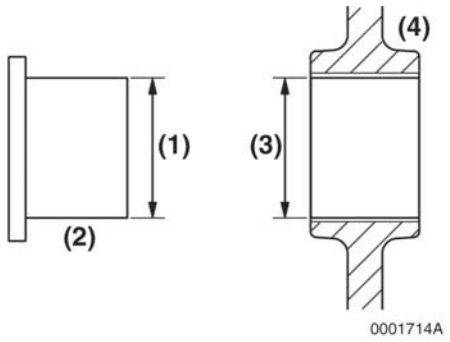


Figure 6-124

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out-of-round, or tapered beyond specifications, rebore and hone to restore cylinders to usable condition. Slight imperfections can be corrected by honing alone.

1. Boring - Significant cylinder damage may be corrected by boring the cylinder to an oversize dimension. Refer to the appropriate parts catalog for available oversize pistons and piston rings.

- Boring a cylinder should always be done in a properly equipped machine shop.
- A bored cylinder should always be finished with a hone to properly prepare the cylinder surface so the new piston rings will seat properly.
- After the cylinder has been bored and honed, install the appropriate oversize pistons and piston rings.

2. Honing - Minor cylinder imperfections may be corrected by using a rigid cylinder hone **(Figure 6-126, (1))**. Be sure not to exceed the maximum cylinder bore specification.
Deglazing - A used cylinder that did not require boring or honing, should always be deglazed with a ball hone **(Figure 6-126, (2))** before installing new piston rings. This will properly prepare the cylinder surface to allow new piston rings to seat properly.

NOTE : When honing a cylinder, with either a ridged hone or a ball hone **(Figure 6-125, (1))**, move the rotating hone up and down in the cylinder bore to accomplish a 30° to 40° crosshatch pattern **(Figure 6-125)**. This will provide the ideal surface for the proper seating of new piston rings.

CAUTION

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

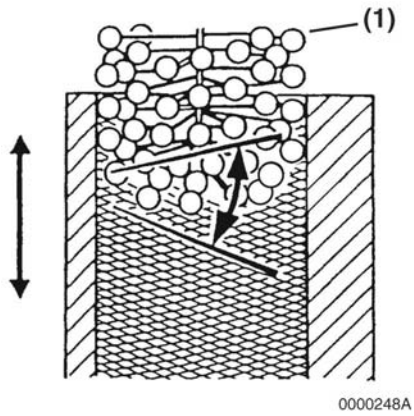


Figure 6-125

- Use a 50:50 mixture of diesel fuel and engine oil as a honing fluid.
- Use a 300-grit hone at 300 - 1200 rpm **(Figure 6-126)**.

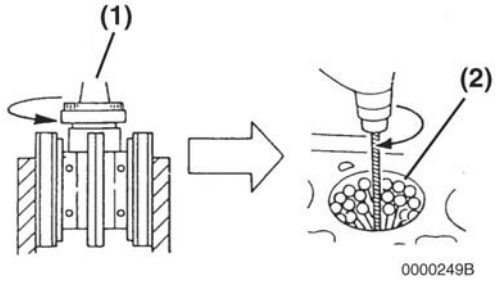


Figure 6-126

IMPORTANT

Solvents will not adequately remove honing residue, resulting in premature piston and ring wear. Always wash cylinders using hot, soapy water.

- When honing is completed, wash the cylinder block with hot water and soap. The cylinder wall is adequately cleaned when a white rag wiped in cylinder comes out clean. Use brushes to clean all passages and crevices. Rinse with hot water and dry with compressed air. Apply clean engine oil to all steel surfaces to prevent rusting.

Reassembly of Crankshaft and Piston Components

NOTES

- Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.
- Use new gaskets, seals and O-rings during assembly.
- Liberally apply clean engine oil to all internal parts during assembly.
- All fasteners should be tightened to a given torque. If a special torque is not provided in the Special Torque Chart on page 73, tighten to standard torque specifications. See Tightening Torques for Standard Bolts and Nuts on page 4-33.

Reassembly of Pistons

4TNV98 Engine

1. Select the parts needed to reassemble the piston and connecting rod for one cylinder.

2. If removed, install a new wrist pin bushing **(Figure 6-127, (7))** using a press and the appropriate service tool. Be sure to align the oil holes.

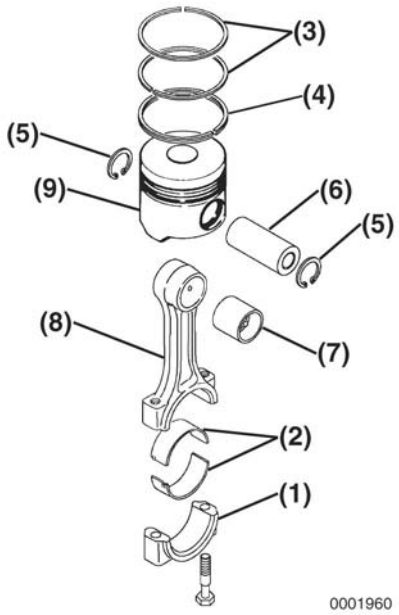


Figure 6-127

3. Reinstall one circlip **(Figure 6-127, (5))** into the piston. Ensure the circlip is securely seated in the groove.

IMPORTANT

The piston and connecting rod must be assembled together in the correct orientation. The orientation of the piston and connecting rod are **different** depending on engine model.

Piston to Connecting Rod Orientation - By Model
Orient the piston identification mark stamped on top of the piston on the same side as the rod and cap match marks stamped on the connecting rod.

NOTE : The actual appearance of the match marks on the piston and connecting rod may vary, but they will always be in the same locations.

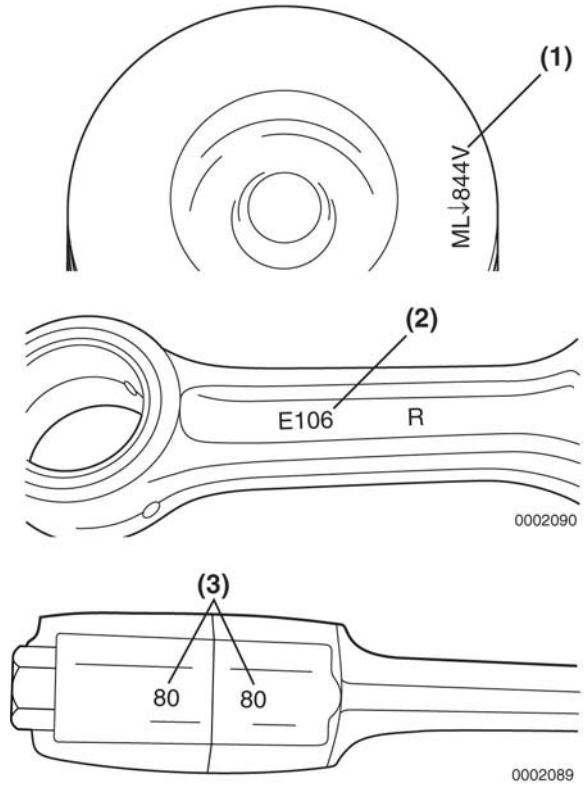


Figure 6-128

(1) Piston Identification Mark.
(2) Embossed Mark on Connecting Rod.
(3) Rod and Cap Match Marks.

Piston Assembly

When correctly assembled, the piston identification mark **(Figure 6-129, (2))** stamped into the top of the piston will be on the same side of the connecting rod as the match marks **(Figure 6-129, (4))** stamped into the connecting rod and connecting rod cap.

When installed in the cylinder, the piston identification mark **(Figure 6-129, (2))** stamped on the top of the piston must face the fuel injection pump side **(Figure 6-129, (1))** of the engine and the embossed mark on the connecting rod **(Figure 6-129, (3))** must face the flywheel end **(Figure 6-129, (5))** of the engine.

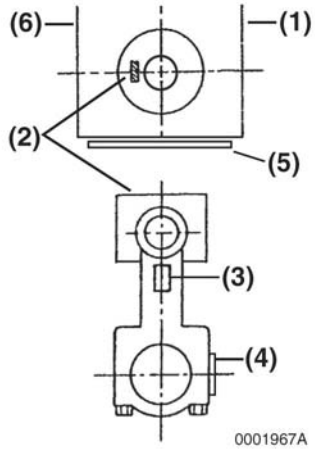


Figure 6-129

(1) Fuel Injection Pump Side of Engine.
(2) Piston Identification Mark.
(3) Embossed Mark on Connecting Rod.
(4) Rod and Cap Match Marks.
(5) Flywheel End of Engine.
(6) Camshaft Side of Engine.

1. Lubricate and reinstall the wrist pin **(Figure 6-131, (3))** through the piston and connecting rod.

2. Reinstall the second circlip **(Figure 6-131, (4))** and ensure it is securely seated in the groove.

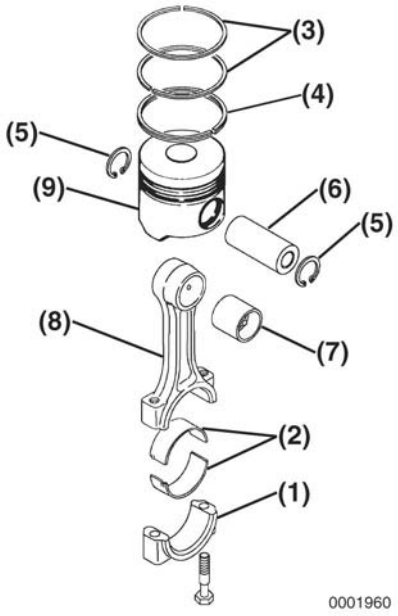


Figure 6-131

NOTE : If installing new piston rings the end gap must be checked and adjusted as necessary. See Inspection of Pistons, Piston Rings and Wrist Pin on page 122 for specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

NOTE : Reinstall the top and second piston rings with the stamped “makers mark” **(Figure 6-132, (1))** facing the top of the piston. The “makers mark” may vary in appearance but will always be located on the top surface of the piston ring adjacent to the piston ring gap. The oil ring and oil ring expander can be installed either side up.

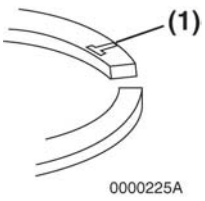


Figure 6-132

IMPORTANT

Always use a piston ring installation tool (expander) when installing piston rings. Never attempt to install piston rings by hand.

3. Reinstall the oil ring expander **(Figure 6-133, (4))**. Reinstall the oil ring **(Figure 6-133, (3))** with the end gap at 180° from the expander end gap.

4. Reinstall the second compression ring **(Figure 6-133, (2))**. This ring is identified by its dark color and tapered face profile.

5. Reinstall the top compression ring **(Figure 6-133, (1)).** This ring is identified by its silver color and barrel-shaped face profile.

IMPORTANT

The oil ring expander **(Figure 6-133, (4))** end gap must be located 180° from the oil ring **(Figure 6-133, (3))** end gap.

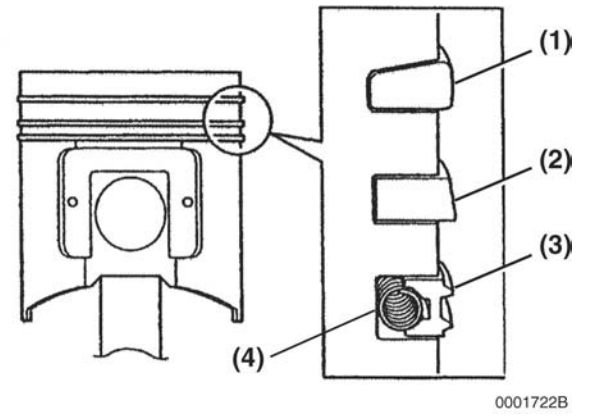


Figure 6-133

6. Stagger the piston ring end gaps at 120° intervals **(Figure 6-134, (1, 2, 3))**. Do not position the top piston ring end gap in line with the wrist pin.

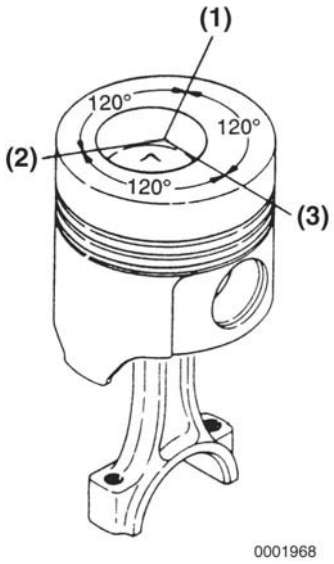


Figure 6-134

(1) Top Compression Ring End Gap.
(2) Second Compression Ring End Gap.
(3) Oil Ring End Gap.

4TNE98 Engine

1. Select the parts needed to assemble the piston and connecting rod for the No.1 cylinder.

2. Lubricate and insert the wrist pin bushing **(Figure 6-70, (1))** into the small end of the piston rod.

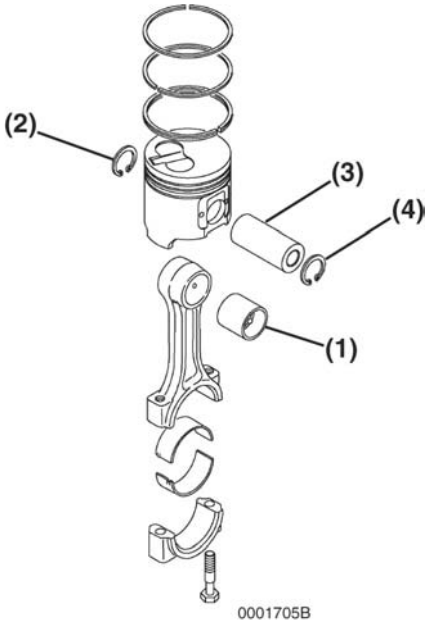


Figure 6-70

3. Install one circlip **(Figure 6-70, (2))** into the piston.

4. Position the connecting rod into the piston under the skirt. The match marks on the connecting rod must be opposite of the piston identification mark (ID) on the top of the piston

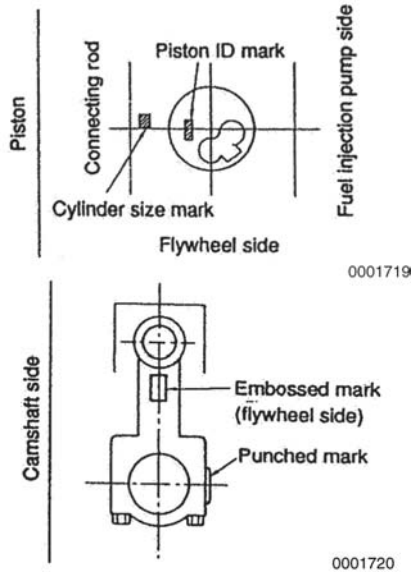


Figure 6-71

7. Lubricate and install the piston wrist pin **(Figure6-70,(3))** through the piston and wrist pin bushing.

6. Install the second circlip **(Figure6-70,(4))**.

7. Install the piston rings:

- Use piston ring pliers to install the piston rings.
- Install each piston ring on the piston with the punched manufacturer's mark **(Figure6-72,(1))** facing upward.

Figure 6-72

- Install the top compression ring, second compression ring and oil ring.

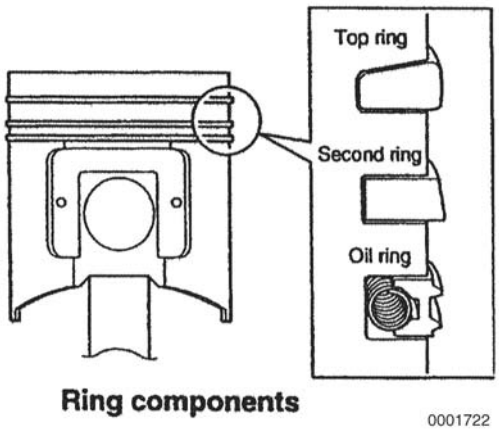


Figure 6-73

- Stagger the piston ring joints at 120 intervals. Do not position the top piston ring joint inline with the piston wrist pin. The coil expander joint must be opposite the oil ring joint.

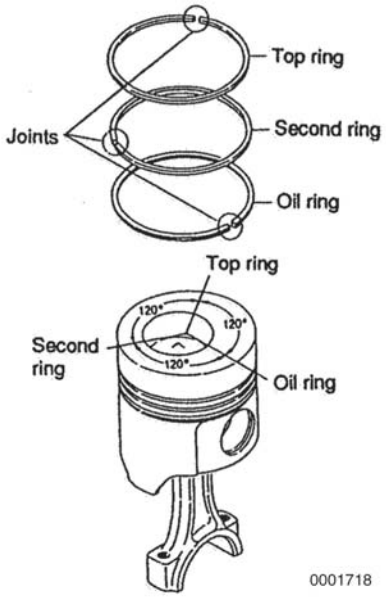


Figure 6-74

• Repeat these steps for the remaining pistons.

Installation of Crankshaft

1. If removed, reinstall the keys and timing gear on the crankshaft.

2. Reinstall new bearing inserts **(Figure 6-135, (1))** and thrust bearing **(Figure 6-135, (2))** in the cylinder block and main bearing caps. Apply a liberal coat of clean engine oil to the bearings and crankshaft journals.

3. Place the crankshaft into the engine.

IMPORTANT

The main bearing caps are numbered and have arrows for proper positioning. The No. 1 cap is at the flywheel end. The arrows point toward the flywheel end of the engine.

4. Reinstall the main bearing caps **(Figure 6-135, (3))**.

5. Apply a light coat of clean engine oil to the bearing cap bolts and tighten the bolts to the specified torque in two stages (1/2 then full torque). See Special Torque Chart on page 6-25 for specifications.

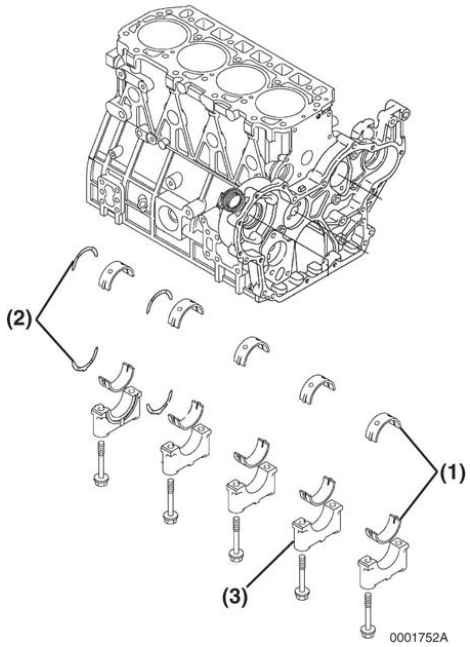


Figure 6-135

6. Rotate the crankshaft to assure it turns freely.

7. Apply ThreeBond Liquid Gasket No. 1212 to the mounting flange of the seal housing **(Figure 6-136, (2))**.

8. Align the seal housing with the two dowel pins.

9. Reinstall seal housing and seal assembly.

10. Reinstall the flywheel **(Figure 6-136, (1))** and tighten the bolts to the specified torque. See Special Torque Chart on page 73 for specifications.

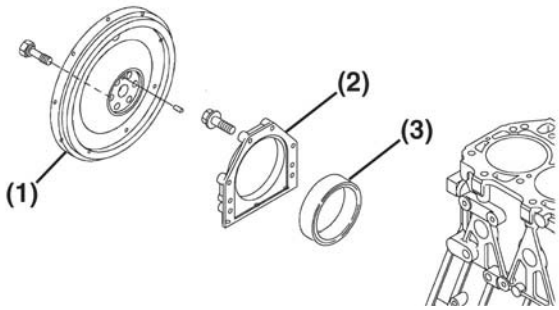


Figure 6-136

Installation of Pistons

IMPORTANT

Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft bearing journal may result.

4TNV98 Engine

1. Lubricate the piston, piston rings, and cylinder with clean engine oil or assembly lubricant.

2. Rotate the crankshaft so the crankpin for the piston being installed is near bottom dead center.

IMPORTANT

Ensure the piston ring gaps are located correctly **(Figure 6-137)**.

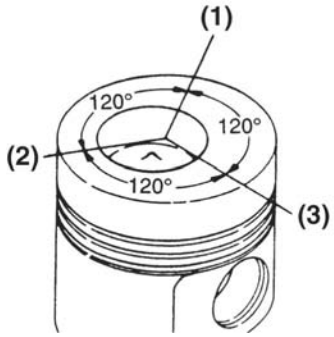


Figure 6-137

(1) Top Compression Ring End Gap.
(2) Second Compression Ring End Gap.
(3) Oil Ring End Gap.

3. Using a piston ring compressor, compress the piston rings.

IMPORTANT

The piston and connecting rod must be installed in the correct orientation. The orientation of the piston to the cylinder is different depending on engine model.

Piston Orientation to Cylinder - By Model
Orient the piston identification mark stamped on top of the piston on the fuel injection pump side of the engine

When correctly assembled, the piston identification mark **(Figure 6-138, (2))** stamped into the top of the piston will be on the same side of the connecting rod as the match marks **(Figure 6-138, (4))** stamped into the connecting rod and connecting rod cap.

When installed in the cylinder, the piston identification mark **(Figure 6-138, (2))** stamped on the top of the piston must face the fuel injection pump side **(Figure 6-138, (1))** of the engine and the embossed mark on the connecting rod **(Figure 6-138, (3))** must face the flywheel end **(Figure 6-138, (5))** of the engine.

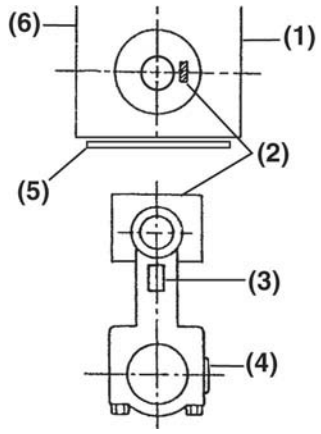


Figure 6-138

(1) Fuel Injection Pump Side of Engine.
(2) Piston Identification Mark.
(3) Embossed Mark on Connecting Rod.
(4) Rod and Cap Match Marks.
(5) Flywheel End of Engine.
(6) Camshaft Side of Engine.

4. Reinstall the bearing inserts **(Figure 6-140, (1))** in the connecting rod and cap.

5. Apply a liberal coat of clean engine oil to the bearing inserts and crankshaft journal.

6. Apply a light coat of clean engine oil to the rod cap bolts. Reinstall the connecting rod cap **(Figure 6-140, (2))**. Tighten the connecting rod bolts to the specified torque in two stages (1/2 then full torque). See Special Torque Chart on page 69 for specifications.

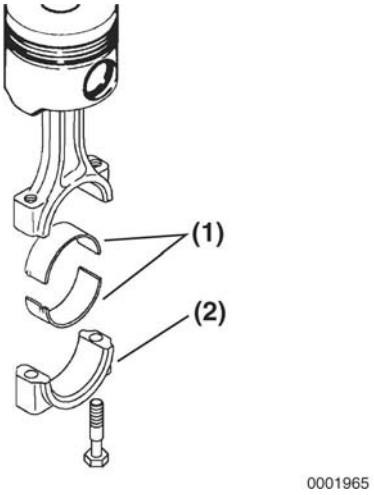


Figure 6-140

7. Reinstall the remaining pistons in their respective cylinders.

4TNE98 Engine

1. Lubricate No. 1 piston and piston rings.

2. Using the piston insertion tool (piston ring compressor), compress the piston rings on the No.1 piston.

3. Carefully install the piston into No.1 cylinder. Be sure the punched mark on the connecting rod is facing the fuel injector side and the embossed mark on the connecting rod is facing the flywheel.

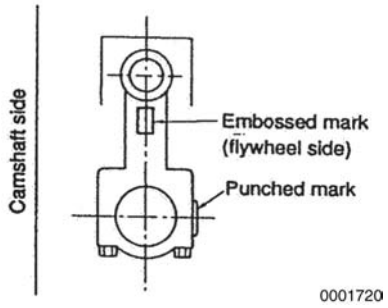


Figure 6-78

4. Install the connecting rod bearing halves **(Figure6-79,(1))** and connecting rod cap **(Figure6-79,(2))**. Tighten the connecting rod bolts to the specified torque.

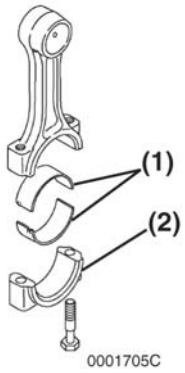


Figure 6-79

5. Install the remaining pistons in their respective cylinders.

Reassembly of Camshaft and Timing Components

Installation of Gear Case or Front Plate

1. If removed, install a new camshaft bushing **(Figure 6-141, (3))** using the appropriate service tool.

2. Apply a continuous bead of Three Bond Liquid Gasket No. 1212 to the mounting area of the gear case or front plate. Be sure to circle each bolt hole.

3. Install two new O-rings **(Figure 6-141, (2))** in the cylinder block.

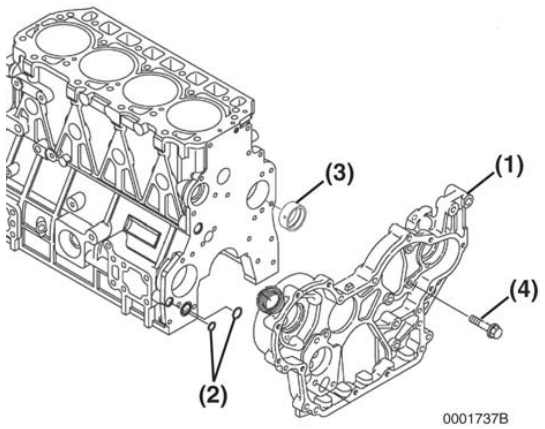


Figure 6-141

4. Reinstall the gear case (Figure 6-141, (1)) Tighten the bolts to the specified torque.

Installation of Camshaft

NOTE : The gear housing or front plate must be reinstalled prior to installing the camshaft. See Installation of Gear Case or Front Plate on page 136.

1. If removed, reinstall the camshaft end plate **(Figure 6-143, (1))**, key, and timing gear **(Figure 6-143, (4))** onto the camshaft using a press.

NOTE : Heat the gear to 356 - 392°F (180 - 200°C) and press onto the end of the camshaft.

2. Rotate the cylinder block so that gravity will keep the tappets **(Figure 6-143, (5))** in place and out of the way of the camshaft lobes when the camshaft is being reinstalled.

NOTE : If the engine is not installed on an engine repair fixture, stand the engine upright on the flywheel end mounting flange.

NOTE : The tappets are “mushroom” shaped and must be installed from inside the engine crankcase.

3. Lubricate the tappets with clean oil or assembly lube. Reinstall the tappets in their respective locations in the cylinder block. Push the tappets fully into the tappet bores so they will not interfere with the installation of the camshaft.

4. Lubricate the camshaft **(Figure 6-143, (2))** with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine.

5. Reinstall and tighten the cap screws **(Figure 6-143, (3))**.

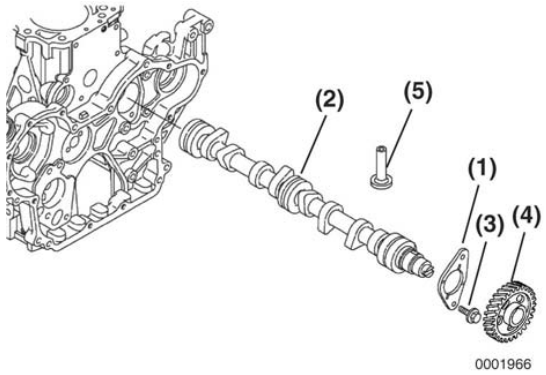


Figure 6-143

6. If removed, reinstall the fuel injection pump. Adjust the fuel injection timing the engine after installation. See Adjusting Fuel Injection Timing on page 161.

Installation of Timing Gears

1. Set the No. 1 piston to top dead center.

2. Rotate the camshaft until the mark **(Figure 6-144, (C))** is approximately at the 9 o’clock position.

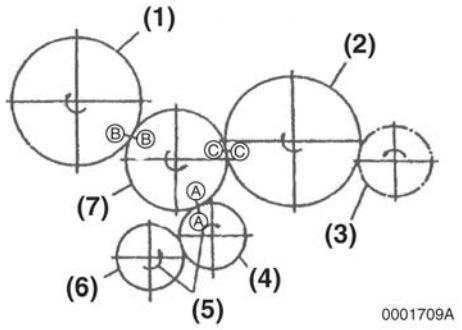


Figure 6-144

(1) Fuel Injection Pump Gea.r
(2) Camshaft Gear.
(3) Optional Accessory Drive Gear.
(4) Crankshaft Gear.
(5) Direction of Rotation.
(6) Oil Pump Gear.
(7) Idler Gear.

3. Lubricate the idler gear **(Figure 6-145, (2))**, bushing **(Figure 6-145, (3))** and idler gear shaft **(Figure 6-145, (1))** with clean engine oil.

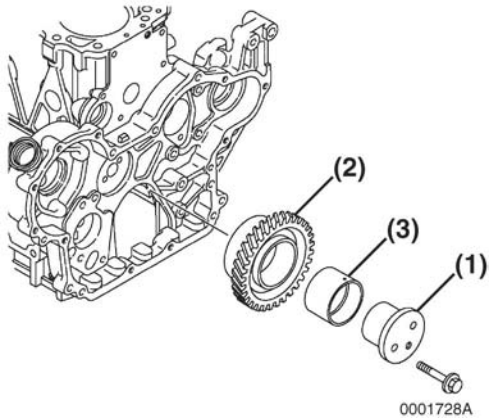


Figure 6-145

4. Align the timing gears as shown in **(Figure 6-144)**.

5. Reinstall the idler gear and idler gear shaft. Be sure the oil hole in the bushing is facing toward the top of the engine.

6. Ensure all three timing marks **(Figure 6-144, (A, B, C))** are aligned.

7. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque. See Special Torque Chart on page 73 for specifications.

Installation of Gear Case Cover

1. Apply a continuous bead of Three Bond Liquid Gasket No. 1212, Yanmar Part No. 977770-01212 to the mounting area of the gear case cover **(Figure 6-146, (1))**. Be sure to circle the bolt holes.

2. Reinstall and tighten the gear case cover bolts.

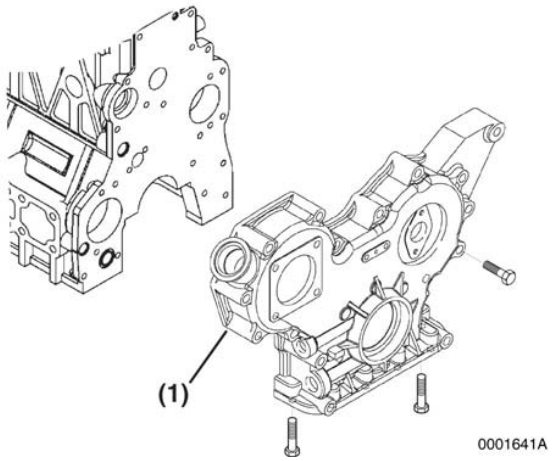


Figure 6-146

3. Reinstall the crankshaft pulley.

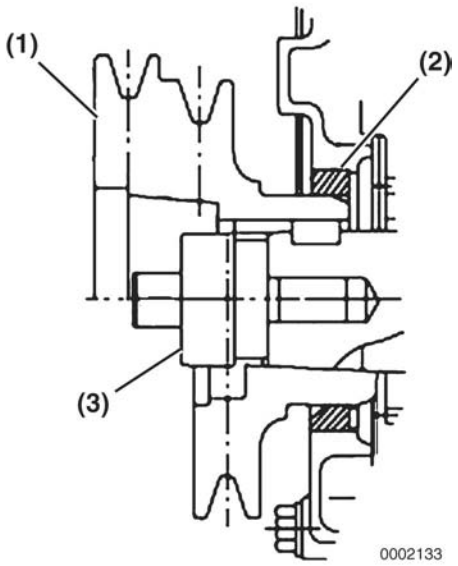


Figure 6-147

4. Reinstall the washer and bolt. Tighten the bolt to the specified torque. See Special Torque Chart on page 73 for specifications.

Installation of Oil Pan

1. Reinstall the oil pickup tube **(Figure 6-148, (1))** using a new O-ring **(Figure 6-148, (2))**.

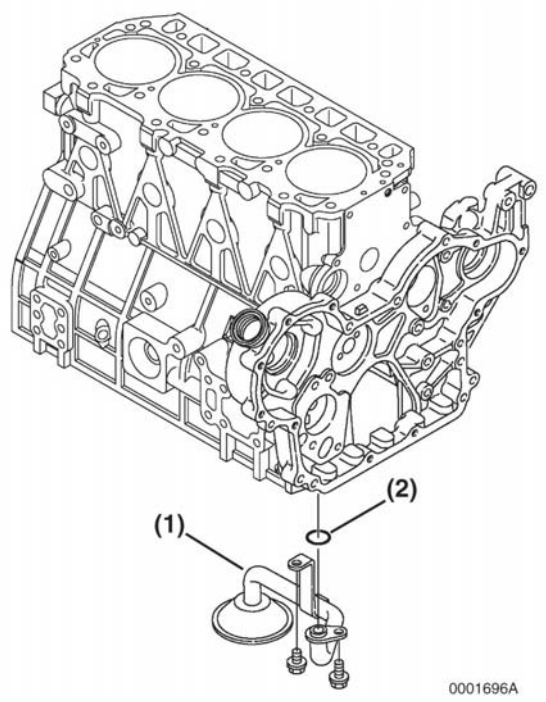


Figure 6-148

2. Apply a continuous bead of ThreeBond Liquid Gasket No. 1212 to the mounting surface of the oil pan **(Figure 6-149, (1))**. Be sure to circle each bolt hole.

3. Reinstall the oil pan and tighten the bolts securely.

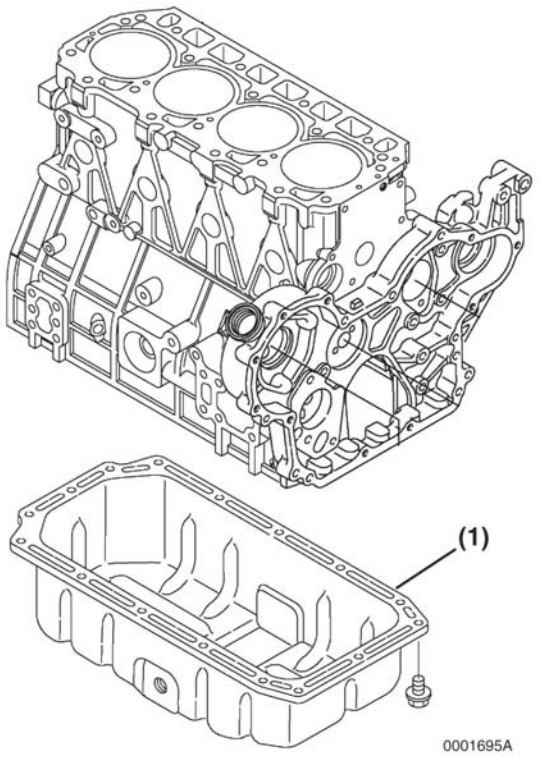


Figure 6-149

Final Reassembly of Engine

1. Reinstall the starter motor.

2. Reinstall the cylinder head. See Reassembly of Cylinder Head on page 88 for the 4-valve cylinder head.

3. Reinstall the engine in the machine.

4. Reconnect the fuel and coolant lines.

5. Reinstall the alternator.

6. Reconnect and adjust the throttle cable.

7. Reconnect all electrical connections.

8. Fill the engine with oil and coolant.

9. Reconnect the battery cables, negative (-) cable ast.

Section 4. FUEL SYSTEM

Before You Begin Servicing

⚠ WARNING

ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it.

NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.

Failure to comply could result in death or serious injury.

⚠ WARNING

SUDDEN MOVEMENT HAZARD!

Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.

Failure to comply could result in death or serious injury.

⚠ WARNING

Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.

⚠ WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

⚠ CAUTION

PINCH HAZARD!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

⚠ CAUTION

NEVER remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

NEVER attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.

Tampering with or removing these devices may void the "Yanmar Limited Warranty."

⚠ CAUTION

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

⚠ CAUTION

Allow the engine to warm-up for at least five minutes and the idle speed of the engine to return to normal before engaging the transmission or any PTOs. Engaging the transmission or PTO at an elevated engine speed could result in an unexpected movement of the equipment.

⚠ CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

⚠ CAUTION

After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel injection pump to become misaligned.

⚠ CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.

⚠ CAUTION

Do not rotate the crankshaft with the injection pump removed.

⚠ CAUTION

Each pressure adjusting shim removed or added changes the pressure threshold by approximately 275 psi (1.9MPa, 19kgf/cm^2). Adding adjusting shims increases the threshold pressure. Removing adjusting shims reduces the pressure threshold.

4TNV98 ENGINE

Introduction

This section of the Service Manual describes the procedures necessary to remove, install, and time the MP fuel injection pump and its associated system components. This fuel injection pump is representative of the fuel injection pumps used on other TNV DI model engines.

Fuel Injection Pump

NOTE: If the MP fuel injection pump itself requires servicing, it must be taken to an authorized Yanmar FIE (Fuel Injection Equipment) repair facility.

⚠ CAUTION

NEVER remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

NEVER attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.

Tampering with or removing these devices may void the "Yanmar Limited Warranty."

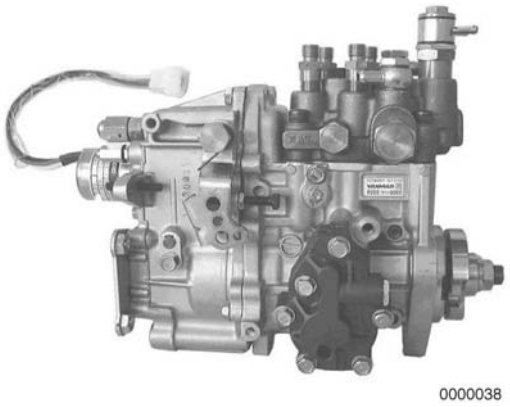


Figure 7-1

The following describes the features of the MP fuel injection pump, manufactured by Yanmar.

The fuel injection pump is a very important component of the engine. It is capable of making very precise fuel delivery adjustments according to the varied loads applied to the engine.

All of the fuel injection pump components are very precisely machined. It is extremely important to follow good service practices and maintain cleanliness when servicing the fuel injection pump.

The Yanmar MP "Mono-Plunger" Fuel Injection Pump is a distributor type pump which consists of a single fuel supply plunger, a distributor shaft, a hydraulic head and a pump housing. The hydraulic head has a delivery valve for each cylinder. The fuel injection pump housing contains a governor and an internal camshaft.

The fuel is pressurized by the up and down motion of the camshaft-driven single plunger. It is then distributed to the proper fuel injector by the rotating distributor shaft.

There are two versions and sizes of the MP Fuel Injection Pump. The smaller of the two pumps, the MP2 pump, is used on the 3TNV82A - 4TNV88 model engines. The larger pump, the MP4 pump, which has a larger single plunger and a more aggressive cam profile, is used on the 4TNV94L-4TNV106T model engines.

Stop Solenoid

The MP fuel injection pumps are equipped with a stop solenoid that controls the fuel flow inside the fuel injection pump.

With the starter switch in the OFF position, no current flows to the stop solenoid and the solenoid plunger is extended holding the fuel injection pump fuel rack in the “closed” position and not allowing fuel to flow through the injection pump and to the engine.

When the starter switch is turned to the start position, the “pull coil” (36.5 Amp draw/white wire) inside the solenoid is activated and pulls the solenoid plunger into the solenoid. This releases the fuel injection pump fuel rack, allowing fuel to flow through the injection pump and allowing the engine to start and run.

When the starter switch is returned to the ON or RUN position, the “pull coil” no longer receives current and the “hold coil” (0.5 Amp draw/red wire) inside the solenoid is activated. The “hold coil” holds the solenoid plunger in the RUN position, allowing fuel to continue flowing and he engine to continue running.

To stop the engine, the key switch is turned to the OFF position. Current no longer flows to the stop solenoid “hold coil”, and the solenoid plunger extends and moves the injection pump fuel rack to the “closed” position, shutting off the fuel flow and stopping the engine.

Failure of the stop solenoid could result in the engine not starting, the engine stopping suddenly, the engine not continuing to run with the key switch returned to the ON or RUN position, or the engine failing to stop when the key switch is turned to the OFF position. Use a multimeter or continuity light to check for 12V at the stop solenoid connector in the correct sequence.

Cold Start Device

The Yanmar TNV model engines are equipped with a cold start device (CSD).

The cold start device is located in the upper section of the fuel injection pump and is connected to the engine’s cooling system.

- The cold start device improves engine starting at lower temperatures. At engine cooling system temperatures below 41°F (5°C), the cold start device advances the fuel injection timing and slightly increases the fuel injection volume.

- For approximately the first 5 minutes of operation, the idle speed of the engine will be slightly elevated.

⚠ CAUTION

Allow the engine to warm-up for at least five minutes and the idle speed of the engine to return to normal before engaging the transmission or any PTOs. Engaging the transmission or PTO at an elevated engine speed could result in an unexpected movement of the equipment.

- When the cold start device is activated, you may notice a slight increase in the exhaust smoke of the engine during engine warm-up.

Trochoid Fuel Pump

NOTE: The trochoid fuel pump located on the side of the MP fuel injection pump is not a “fuel supply” pump. The function of this pump is to raise the pressure of the fuel supplied by the electric fuel supply pump to the internal fuel pressure required by the MP fuel injection pump.

The use of an electric fuel supply pump is required on all TNV model engines with the MP fuel injection pump.

Fuel System Specifications

Special Torque Chart

Component		Tightening Torque	Lubricating Oil Application (Thread Portion and Seat Surface)
Fuel Injector Retainer Bolt		29 ft·lb (39.2 N·m; 4 kgf·m)	Not Applied
Fuel Pump Drive Gear Nut	4TNV98	83-91 ft·lb (113-123 N·m; 11.5-12.5 kgf·m)	Not Applied
High-Pressure Fuel Injection Line Nuts		22-25 ft·lb (29-34 N·m; 3.0-3.5 kgf·m)	Not Applied
Fuel Return Line Bolts		69-87 in·lb (7.8-9.8 N·m; 0.8-1.0 kgf·m)	Not Applied
Fuel Injection Pump Mounting Nuts		17-21 ft·lb (23-28 N·m; 2.3-2.9 kgf·m)	Not Applied
Fuel Injector Nozzle Case Nut		30-33 ft·lb (39.2-44.1 N·m; 4-4.5 kgf·m)	Not Applied
Fuel Injection Pump Plunger Plug	4TNV98	30-33 ft·lb (40-45 N·m; 4.1-4.6 kgf·m)	Not Applied

Test and Adjustment Specifications

Model	Engine Class	Injector ID mark*	Fuel Injector Pressure	Fuel Injection Timing
4TNV98	VM	V	3133-3278 psi (21.6-22.6 MPa; 220-230 kgf/cm²	See Checking and Adjusting Fuel Injection Timing on page 157

NOTE: Fuel injection pressure of a new fuel injector is reduced approximately 72.5 psi (0.5 MPa; 5.0 kgf/cm²) after about 5 hours of operation due to the initial break in of the engine. When adjusting a new fuel injector or after it has been disassembled for service, adjust the fuel injector 72.5 psi (0.5 MPa; 5.0 kgf/cm²) higher than the above standard.

NOTE: All fuel injectors have a three character identification mark **(Figure7-2, (1))**. The first character starts with “V” or “W”.

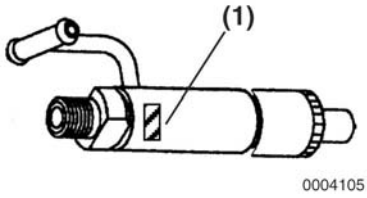
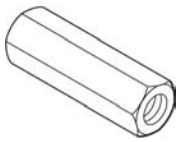


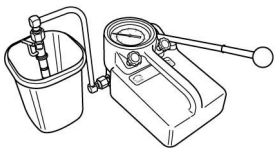
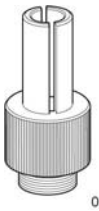
Figure7-2

** Fuel injector identification is critical as each engine has a unique fuel injection pressure. The fuel nozzle is specifically matched to the fuel injector by engine model and / or engine speed.

Special Service Tools

No.	Tool Name		Application	Illustration
1	Torque Wrench	Locally Available	For tightening nuts and bolts to the specified torque	0000840
2	Fuel Injector Removal Tool	Yanmar Part No. 129470-92305	Used in conjunction with a slide hammer to remove the fuel injectors (2-valve cylinder heads)	

Measuring Instruments

No.	Instrument Name		Application	Illustration
1	Fuel Injector Tester	Locally Available	For observing injection spray pattern of fuel injection nozzle and measuring injection pressure	
2	Dial Indicator*	Mituotoyo 2050SB-Locally Available	Check and adjust fuel injection timing	0000831
	Extension Rod*	Mituotoyo 303613-Locally Available		
3	Fuel Injection Pump Plunger Adapter*	(M16) 4TNV98 Yanmar Part No. 158090-51841	Mount dial indicator to fuel injection pump	 0002690
4	Plunger Adapter Clamp	Yanmar Part No. 23000-013000	Clamps stem of dial indicator in plunger adapter.	0002691

* These special service tools may also be available as an “MP Fuel Injection Pump Special Tool Set”, under a different part number, in territories serviced by Yanmar America and Yanmar Europe. Contact your authorized Yanmar dealer or distributor for details.

Fuel System Diagram

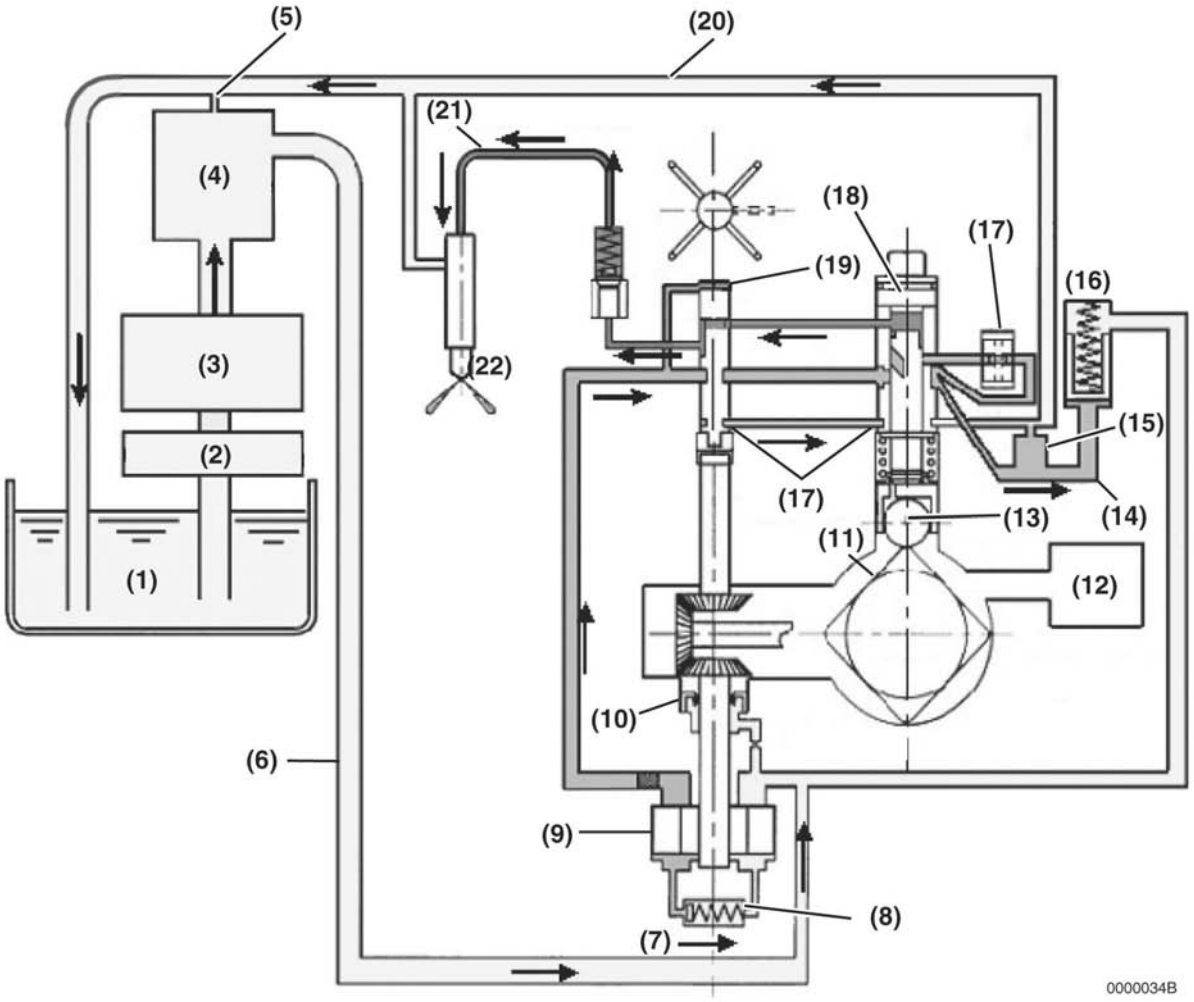


Figure7-3

(1) Diesel Fuel Tank. (2) Fuel Filter / Water Separator. (3) Electric Fuel Pump. (4) Fuel Filter. (5) Air Bleed Orifice. (6) Fuel Supply Line.
(7) Low Pressure Gallery. (8) Pressure Control Valve. (9) Trochoid Pump. (10) Oil Seal. (11) Fuel Injection Pump Cam.
(12) Engine Crankcase. (13) Tappet. (14) High Pressure Gallery. (15) Overflow Orifice. (16) Accumulator. (17) Timer Piston.
(18) Mono-Plunger. (19) Distributor Shaft. (20) Fuel Return Line. (21) High-Pressure Fuel Injection Lines. (22) Fuel Injector.

Fuel System Components

4-Valve Cylinder Head

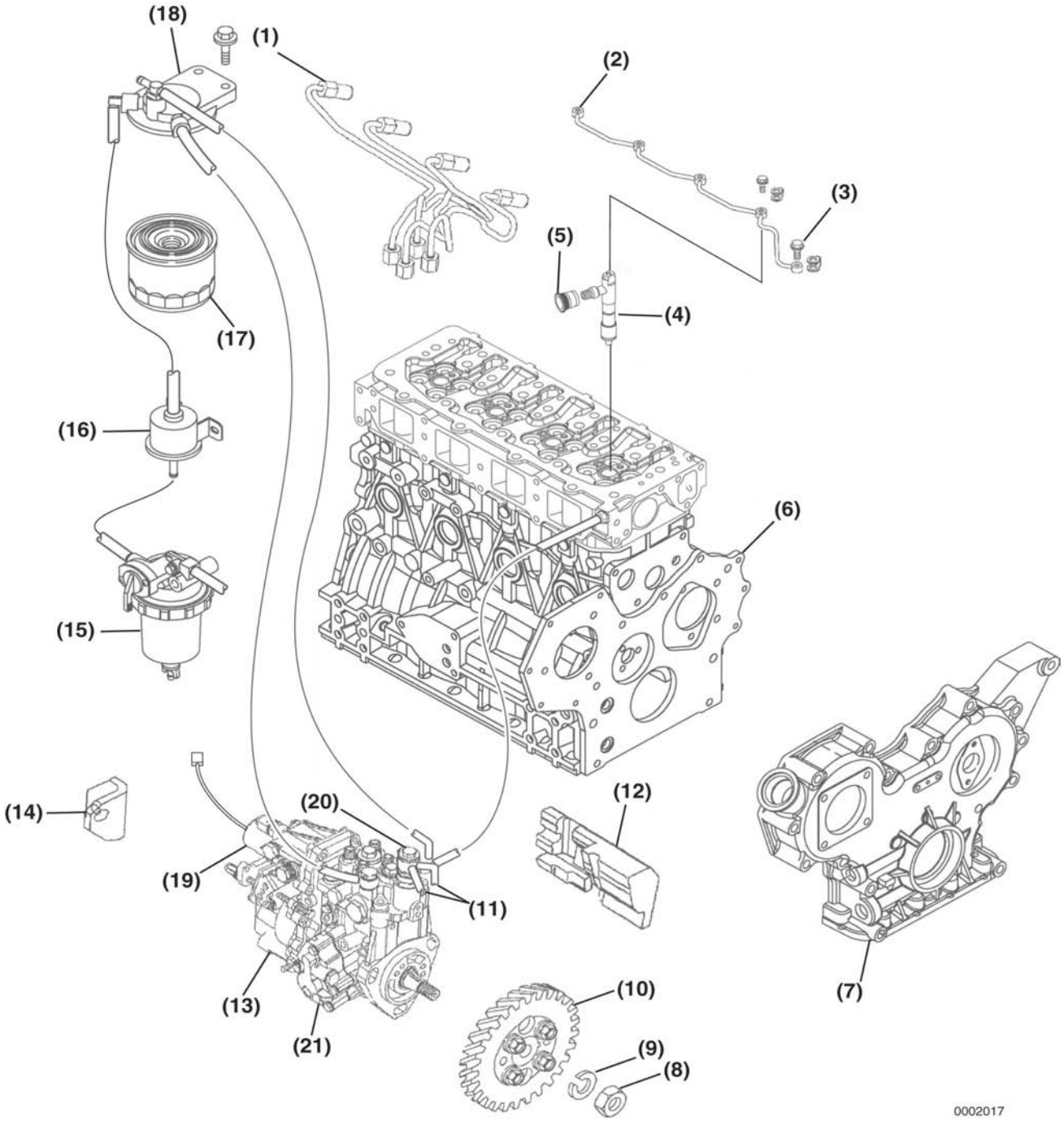


Figure 7-5

(1) High-Pressure Fuel Injection Lines. (2) Fuel Return Line. (3) Return Line-to-Cylinder Head Bolt (4) Fuel Injector.
(5) Injection Line Grommet. (6) Front Plate or Timing Gear Case. (7) Gear Case Cover. (8) Fuel Injection Pump Drive Gear Nut.
(9) Lock Washer. (10) Fuel Injection Pump Drive Gear Assembly (DO NOT remove or loosen the four bolts that fasten the injection pump drive gear to the injection pump drive gear hub!). (11) Coolant Lines for Cold Start Device. (12) Fuel Injection Pump Insulator.
(13) Diesel Fuel Injection Pump. (14) Rear Fuel Injection Pump Support. (15) Fuel Filter / Water Separator.
(16) Electric Fuel Supply Pump. (17) Fuel Filter. (18) Fuel Filter Housing. (19) Stop Solenoid. (20) Cold Start Device (CSD).
(21) Trochoid Fuel Pump

Fuel Injection Pump

Removal of Fuel Injection Pump

1. Loosen the cooling fan V-belt.

2. Remove the engine coolant fan guard (if equipped), engine coolant fan **(Figure7-6, (2))**, spacer **(Figure7-6, (3))** if equipped, V-pulley **(Figure7-6, (4))** and cooling fan V-belt **(Figure7-6, (1))**.

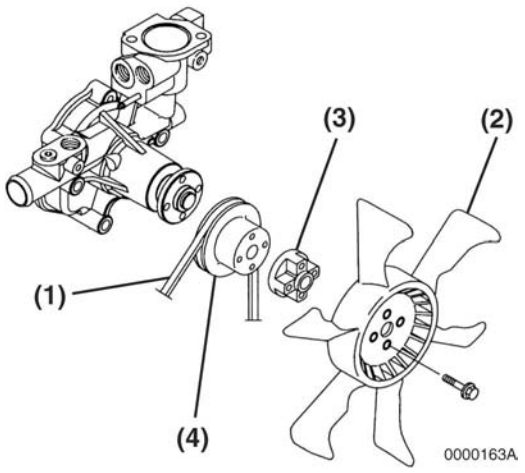


Figure 7-6

3. Close any fuel valves in the fuel supply line.

4. Place a drain pan under the fuel injection pump to catch any spillage.

5. Remove the high-pressure fuel injection lines as an assembly **(Figure 7-7, (1))**.

NOTICE

To prevent “rounding” the fuel line nuts always use a “line” or “flare nut” wrench. When loosening the fuel line nuts, always hold the fuel injection pump delivery valves with a “back up” wrench to prevent loosening of the delivery valves.

6. First loosen the fuel line nuts at the fuel injectors and then at the fuel injection pump.

⚠ CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

7. Finish loosening all the fuel line nuts and remove the high-pressure fuel lines as an assembly being careful not to bend any of the fuel lines. Be sure to protect the fuel system from contamination by covering all open connections.

8. Disconnect the coolant lines from the cold start device **(Figure 7-7, (3))** on the fuel injection pump. Plug the open ends of the lines to minimize leakage and prevent contamination.

9. Disconnect the fuel return lines from the fuel return fitting **(Figure 7-7, (2))**. Plug the open ends of the lines to minimize leakage and prevent contamination.

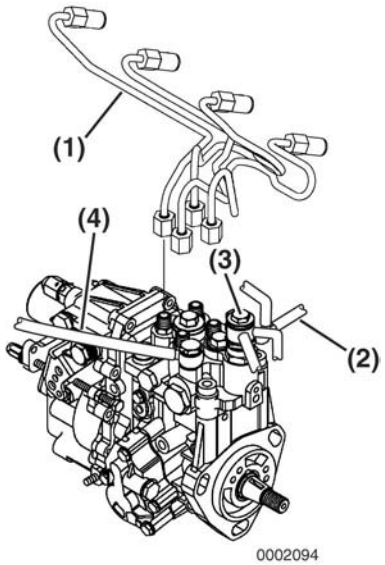


Figure 7-7

10. Remove the fuel supply line **(Figure 7-7, (4))**. Plug the open end of the line to minimize leakage and prevent contamination.

11. Remove the throttle cable from the fuel injection pump.

12. Separate the stop solenoid wiring connector **(Figure 7-8, (2))**.

13. Remove the rear fuel injection pump bracket(s) **(Figure 7-8, (1))** from the fuel injection pump.

NOTE: Configuration of the fuel injection pump rear brackets may vary depending upon engine model.

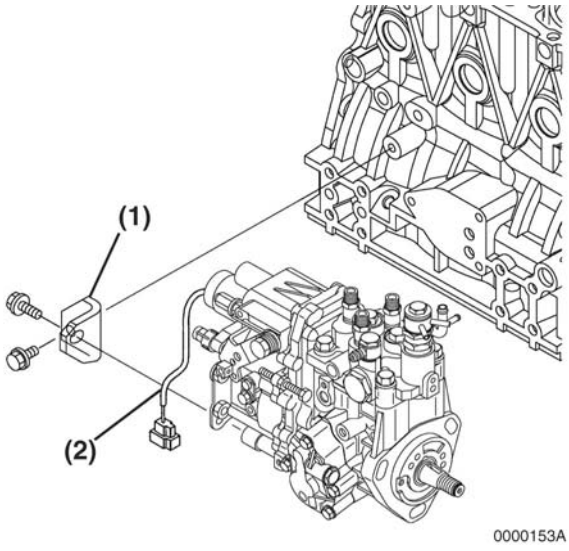


Figure 7-8

14. Disconnect the lube oil line **(Figure 7-9, (1))** and the clamp **(Figure 7-9, (2))** from the pump.

IMPORTANT

Take care to not damage or bend the oil line. In some applications, it may be preferable to remove the complete oil line assembly from the engine before proceeding.

NOTE: On models 4TNV98, the cover is larger and retained by 7 bolts.

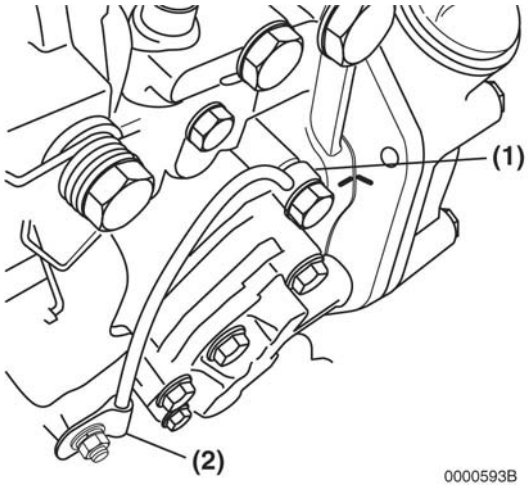


Figure 7-9

15. Remove the fuel injection pump drive gear cover **(Figure7-10, (1))** from the gear case cover **(Figure7-10, (2))**.

NOTE: The fuel injection pump drive gear cover is secured with an adhesive sealant. Use a gasket scraper to separate the fuel injection pump cover from the gear case cover.

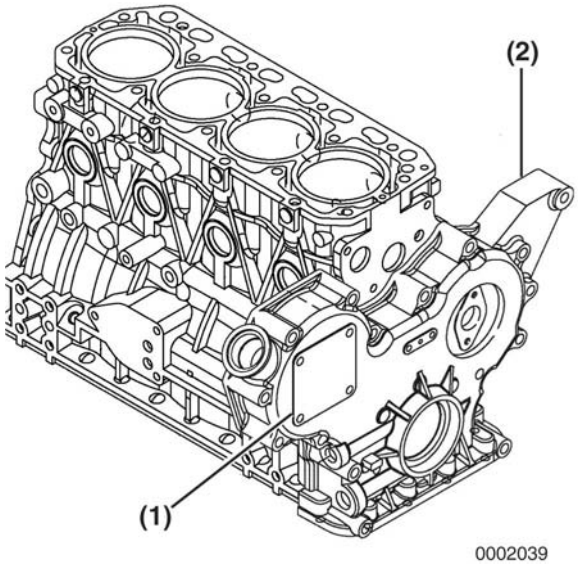


Figure 7-10

NOTE: TNV82-88 shown.

16. To position the fuel injection pump for easier removal and installation, install a dial indicator (see Checking and Adjusting Fuel Injection Timing on page 157) into the injection pump plunger opening. Using a wrench on the crankshaft pulley bolt, rotate the crankshaft until the dial indicator shows that injection pump plunger is at the bottom of it's stroke.

17. To aid in reassembly, make reference marks on the fuel injection pump drive gear, and on either the gear case cover or idler gear.

CAUTION

After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel injection pump to become misaligned.

- On 4TNV98 model engines, the idler gear is visible. Make a reference mark **(Figure 7-12, (1))** across both the fuel injection pump drive gear and the idler gear.

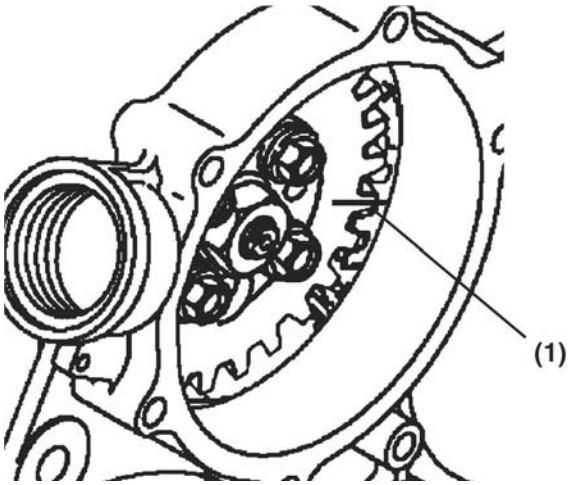


Figure7-12

CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.

18. Do not loosen or remove the four bolts **(Figure7-13, (3))** retaining the pump drive gear to the hub. Only remove the single drive gear nut **(Figure7-13, (1))** and washer **(Figure7-13, (2))**, leaving the hub attached to the gear.

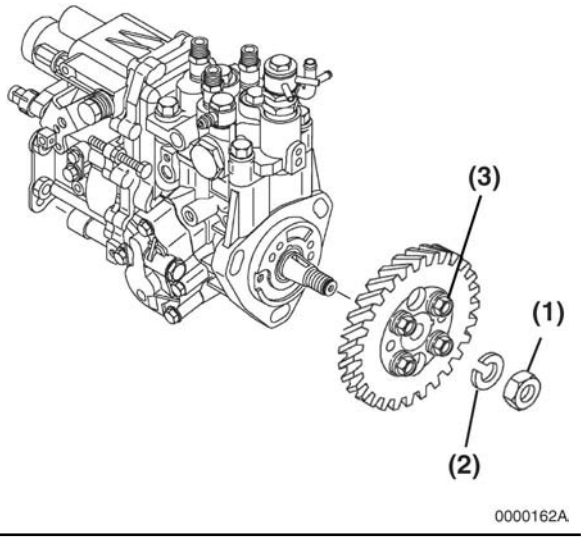


Figure 7-13

19. Hold the gear train using a large socket wrench on the crankshaft pulley nut. Loosen the fuel injection pump drive gear retaining nut **(Figure 7-13, (1))** and turn it out to the end of the fuel injection pump shaft.

20. Remove the pump drive gear and hub as an assembly using an appropriate two-bolt gear puller **(Figure7-14)**.

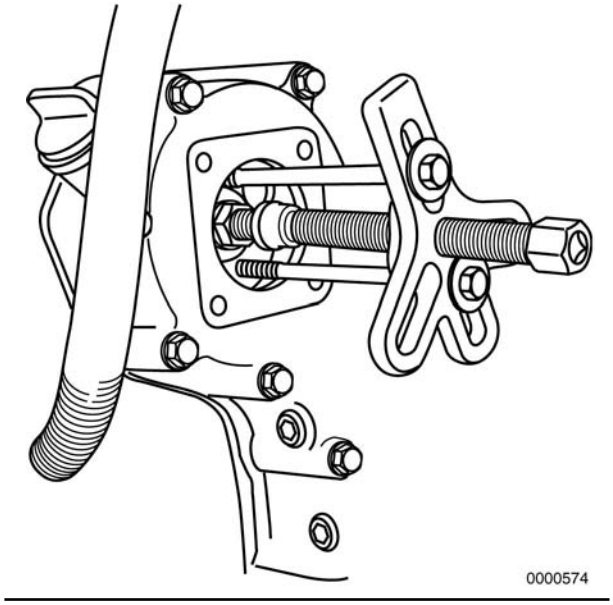


Figure7-14

NOTE: On TNV98 models, the injection pump drive gear can be removed through the gear case cover opening.

21. Once the fuel injection pump drive gear and hub assembly has “popped” loose from the tapered fuel injection pump drive shaft, carefully remove the drive gear nut **(Figure 7-15, (1))** and lock washer **(Figure 7-15, (2))**.

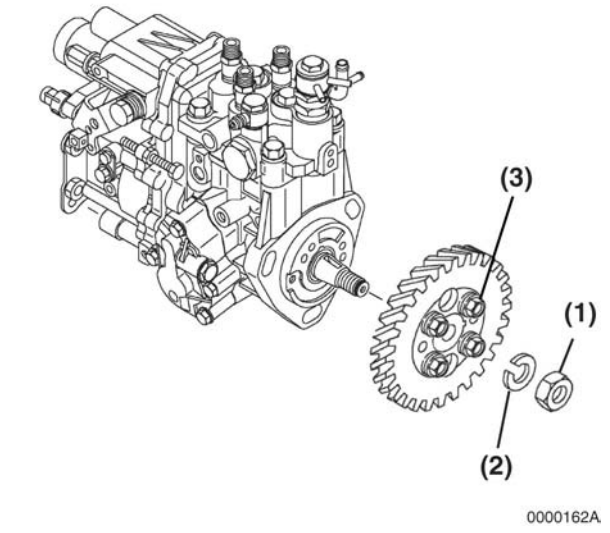


Figure 7-15

22. Locate the mark stamped into the upper outside mounting boss of the fuel injection pump. Highlight this mark and make a corresponding mark on the gear case or front plate **(Figure 7-16, (1))**.

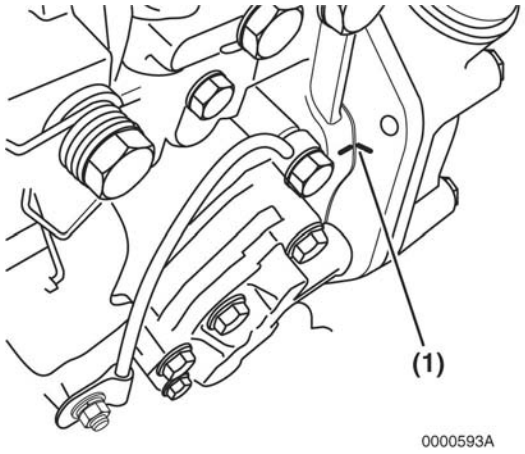


Figure 7-16

NOTE: Some model engines may require the intake manifold and fuel injection pump insulator **(Figure 7-17, (2))** be removed to access the inner fuel injection pump **(Figure 7-17, (1))** retaining nuts.

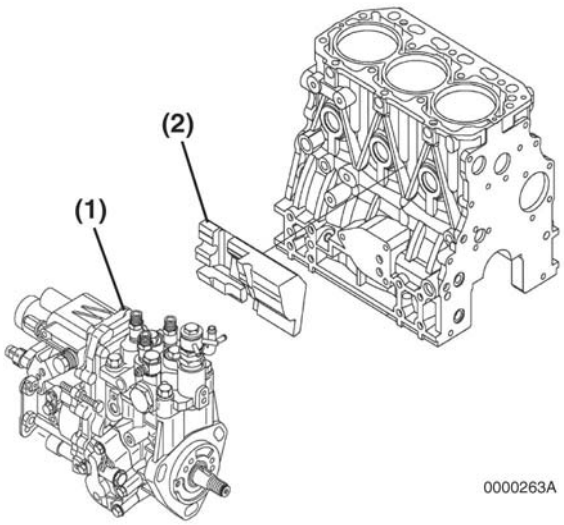


Figure 7-17

23. If required, remove the intake manifold and fuel pump insulator to access the fuel injection pump mounting nuts.

NOTE: The MP4 fuel injection pumps (4TNV98 model engines) are fastened to the gear case with four (4) studs and nuts.

24. Remove the fuel injection pump **(Figure 7-17, (1))**. For purposes of future injection timing purposes, record the fuel injection pump timing index number located on the boss on the engine side (back) of the of the fuel injection pump **(Figure 7-18, (1))**.

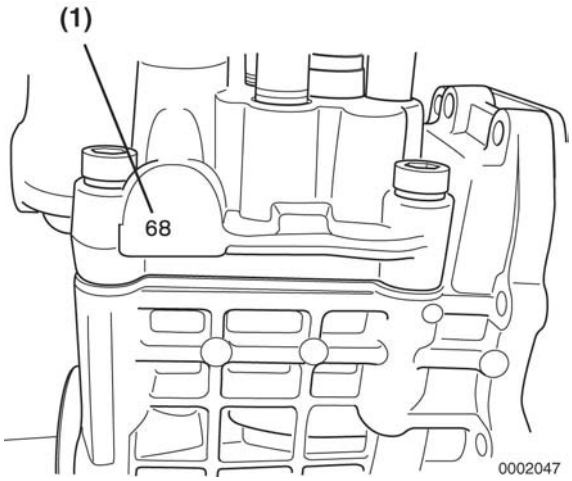


Figure 7-18

CAUTION

Do not rotate the crankshaft with the injection pump removed.

25. If the fuel injection pump requires servicing, it must be sent to an authorized Yanmar FIE repair facility for repair and calibration, or replaced with a new fuel injection pump.

CAUTION

NEVER remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

NEVER attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.

Tampering with or removing these devices may void the "Yanmar Limited Warranty."

Installation of Fuel Injection Pump

IMPORTANT

If installing a new or recalibrated fuel injection pump, locate and record the timing index number located on the pump housing boss on the engine side of the new or recalibrated fuel injection pump (Figure 7-19, (1)). This number will be used to calculate and adjust the final fuel injection timing.

NOTE: If either or both of the fuel injection pumps do not have a timing index number, note the injection pump ID (example: XK42) on the injection pump ID label.

To locate the timing index number for the engine being serviced use the Timing Index Chart under “FIE Specs” on the Yanmar Distributor Website (http://distributor.yanmar.co.jp).
If additional assistance is needed in locating the engine timing index number See To Locate an Authorized Yanmar Industrial Engine Dealer or Distributor: Follow the instructions to locate an authorized Yanmar industrial engine dealer or distributor for assistance.

NOTE: Treat the timing index number as if it has a decimal point (68 = 6.8).

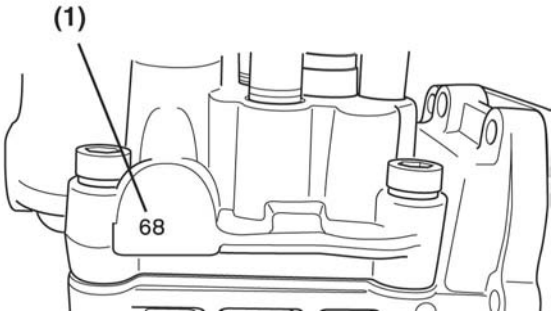


Figure 7-19

1. Align the pump drive gear with the idler gear using the reference marks made earlier. 4TNV98 model engines **(Figure 7-21, (1))**.

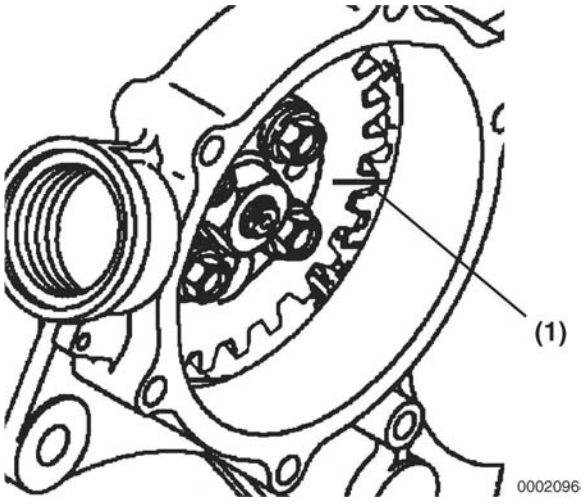


Figure 7-21

2. If installing the fuel injection pump on an engine with the front gear case cover removed, the fuel injection pump drive gear can be aligned with the idler gear by aligning the stamped marks **(A, B, C)** on the fuel injection pump drive gear, idler gear, and crankshaft drive gear. Ensure all three timing marks **(Figure 7-22, (A, B, C)) are aligned**.

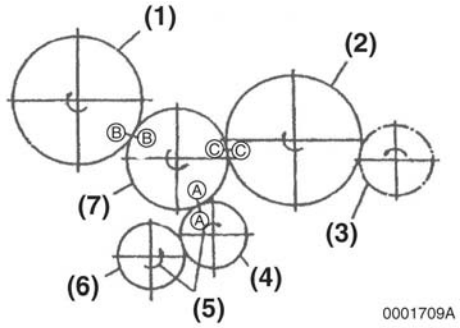


Figure 7-22

(1) Fuel Injection Pump Drive Gear. (2) Camshaft Drive Gear. (3) Auxiliary Drive Gear (Optional). (4) Crankshaft Drive Gear. (5) Direction of Rotation. (6) Oil Pump Drive Gear (4TNV94L - 4TNV106). (7) Idler Gear

3. Install a new O-ring on the pump mounting flange. Apply grease to the O-ring to hold it in place during installation of the injection pump.

NOTE: Ensure the tapered surface of the fuel injection pump shaft is clean and dry.

4. Align the key on the fuel injection pump shaft with the keyway in the fuel injection pump drive gear hub. Reinstall the fuel injection pump into the fuel injection pump drive gear and gear housing. Reinstall the pump retaining nuts finger tight.

5. Reinstall the fuel injection pump drive gear lock washer **(Figure 7-23, (2))** and nut **(Figure 7-23, (1))**. Do not lubricate the threads of the nut or shaft. Hold the crankshaft pulley bolt with a socket wrench and tighten the drive gear nut to the specified torque. See Special Torque Chart on page 143.

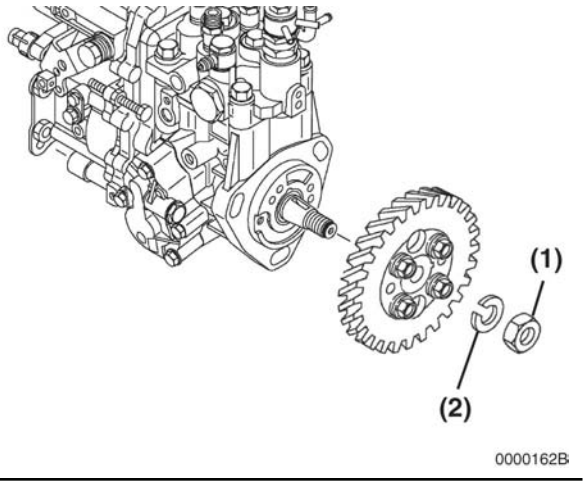


Figure 7-23

If reinstalling the original fuel injection pump:

• Align the reference marks **(Figure 7-24, (1))** previously made on both the fuel injection pump mounting flange and gear case or front plate.

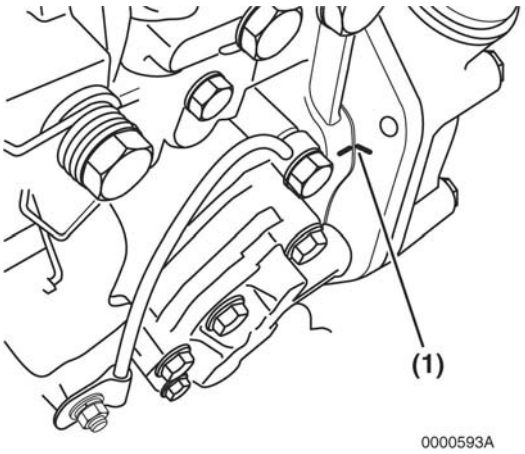


Figure 7-24

• Tighten the fuel injection pump retaining nuts to specification. See Special Torque Chart on page 143.

If installing a new fuel injection pump:

• Reinstall the timing grid sticker, provided with the new fuel injection pump, onto the back of the gear case / front plate **(Figure 7-25)**. Align the “standard mark” **(Figure 7-25, (1))** with the reference mark **(Figure 7-25, (2))** made on the gear case during disassembly.

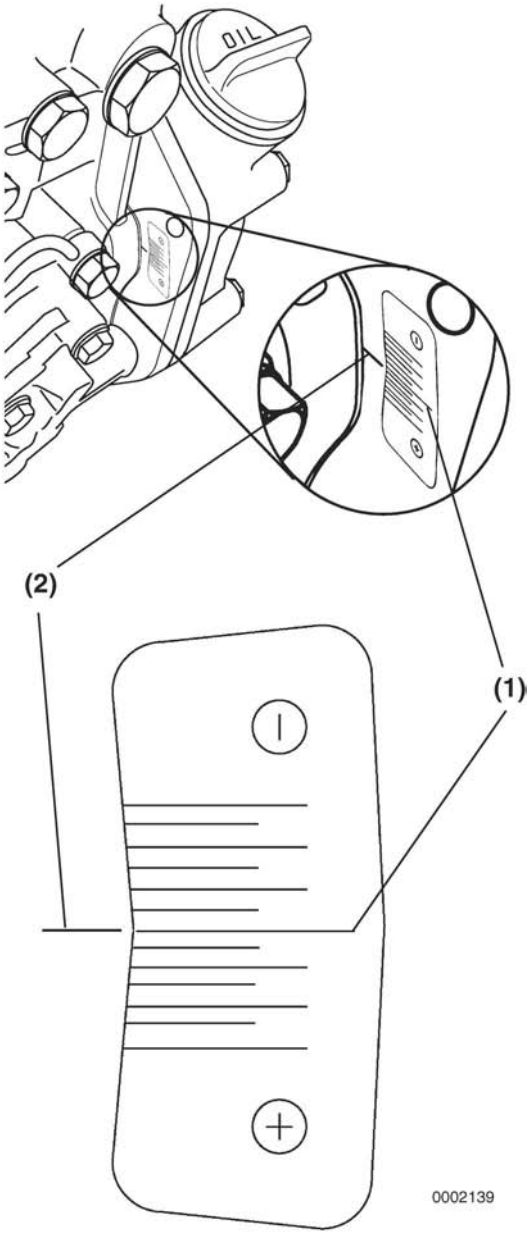


Figure 7-25

• Calculate the difference between the timing index numbers **(Figure 7-26, (1))** of the fuel injection pump that you removed and the replacement fuel injection pump. See Calculation Example below.

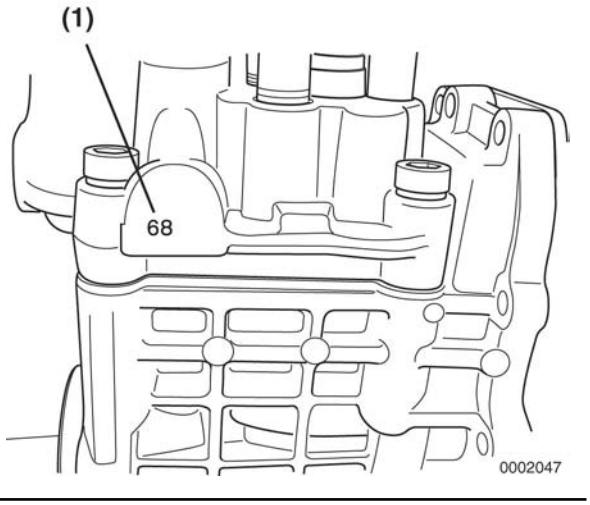


Figure 7-26

Adjusting the fuel injection timing to compensate for the difference in pump timing index numbers:

Calculation Example

Timing Index Number	
Original injection pump=	6.8
Replacement injection pump=	7.3
Difference=	+0.5

• If the difference between the timing index numbers is a positive number, the fuel injection pump mounting position must be advanced **(Figure 7-27, (2))** (rotated away from the engine) as compared to the “standard mark” **(Figure 7-27, (1))** by the calculated positive amount, adjust the fuel injection pump to the calculated value.

• If the difference between the timing index numbers is a negative number, the replacement injection pump must be retarded **(Figure 7-27, (3))** (rotated toward the engine) by the calculated negative amount.

• Each mark on the timing sticker represents 0.5° timing change.

The above calculated difference indicates that the replacement fuel injection pump is to be installed at +0.5° (advanced) from the “Standard Mark” **(Figure 7-27, (1))** on the timing sticker.

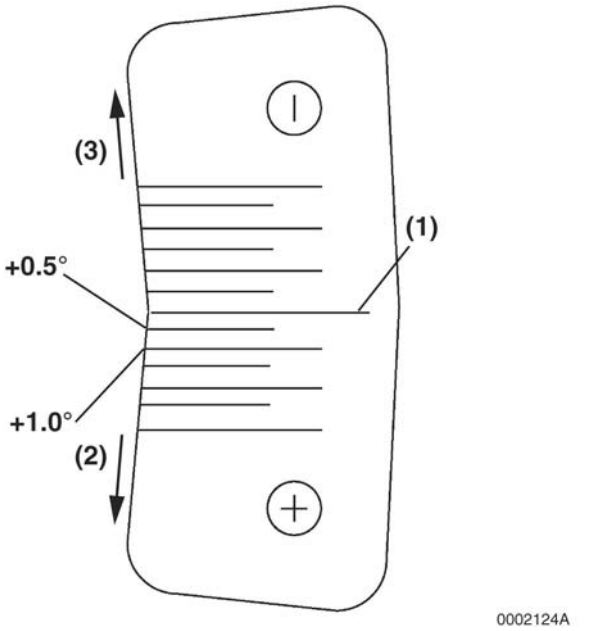


Figure 7-27

In this case, rotate the top of the fuel injection pump away from the cylinder block until the mark on the outside upper mounting boss **(Figure 7-28, (1))** of the fuel injection pump aligns with the +0.5° mark on the timing sticker.

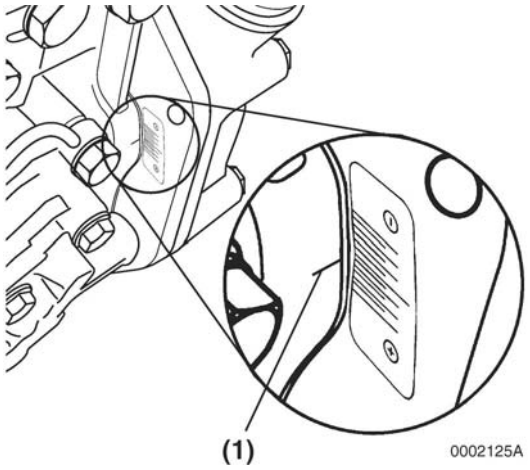


Figure 7-28

Tighten the fuel injection pump mounting nuts to specification. See Special Torque Chart on page 143.

6. Reinstall the rear bracket(s) **(Figure 7-29, (1))** to the fuel injection pump. Tighten the rear support bolts.

NOTE: Configuration of the fuel injection pump rear brackets may vary depending on the model.

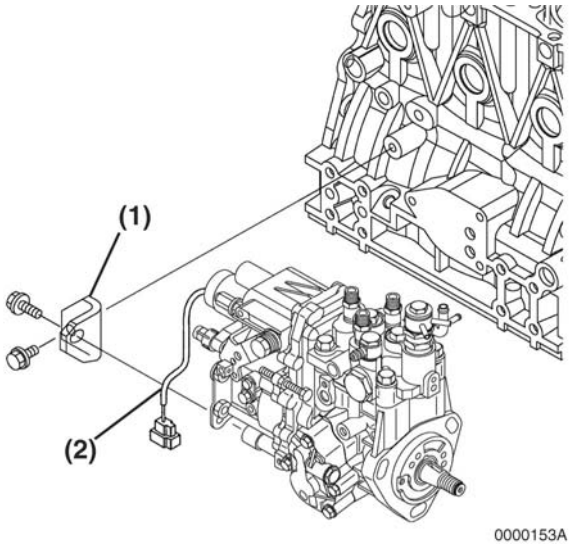


Figure 7-29

7. Reconnect the throttle linkage and the stop solenoid connector **(Figure 7-30, (2))**.

8. Reconnect the lube oil line **(Figure 7-30, (1))** and clamp **(Figure 7-30, (2))**.

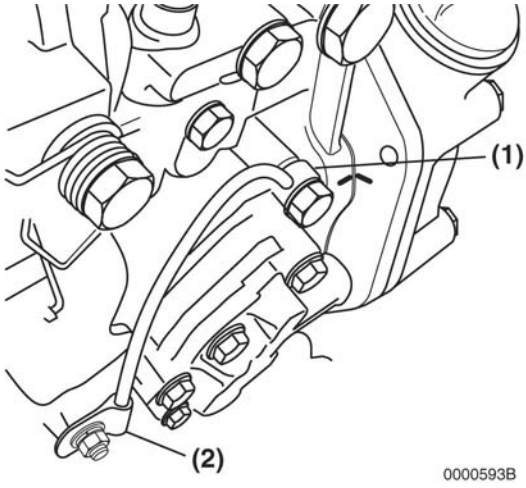


Figure 7-30

9. Apply Three Bond Liquid Gasket No. 1212 or equivalent sealant to the sealing surface of the pump cover. Install the pump cover and tighten the cover bolts.

10. Reconnect the fuel return lines, fuel supply line and coolant lines to the fuel injection pump.

11. Reinstall the fuel injection high-pressure lines. Tighten the nuts to specification. See Special Torque Chart on page 143.

IMPORTANT

When reinstalling a new or repaired fuel injection pump, it is important to add engine oil to the fuel injection pump to provide lubrication for initial start-up. Add 5-7 oz (150-200 cc) of clean engine oil to the fuel injection pump at the fill plug located in the upper outside section of the governor housing.

12. If equipped, verify the fuel injection pump insulator **(Figure 7-31, (2))** is not damaged. Reinstall the insulator and intake manifold if previously removed.

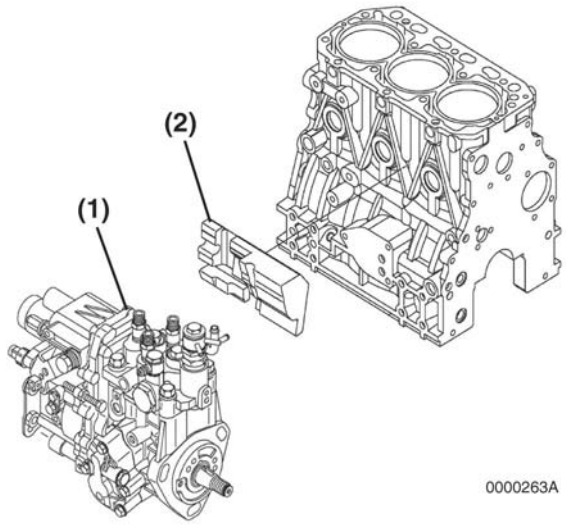


Figure 7-31

13. Reinstall the coolant pump V-pulley **(Figure 7-32, (4))**, spacer **(Figure 7-32, (3))** (if equipped) and engine coolant fan **(Figure 7-32, (2))**.

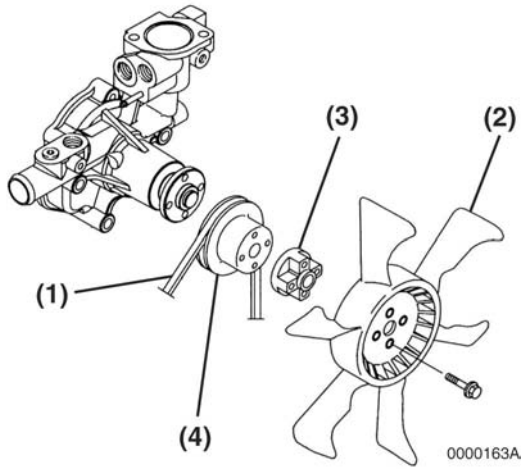


Figure 7-32

14. Reinstall the cooling fan V-belt **(Figure7-32, (1))**. Adjust it as described in Check and Adjust Cooling Fan V-Belt on page 47.

15. Reinstall the cooling fan guard (if equipped).

16. Prime the fuel system. See Priming the Fuel System on page 15.

17. Operate the engine and check for fuel and coolant leaks.

Checking and Adjusting Fuel Injection Timing

Determining the Fuel Injection Timing Specification

1. Locate and record the fuel injection pump timing index number **(Figure 7-34, (1))** stamped into the boss on the engine side of the fuel injection pump housing **(Figure 7-33, (1))**. Treat this number as though there is a decimal point between the two digits. i.e. 68 = 6.8

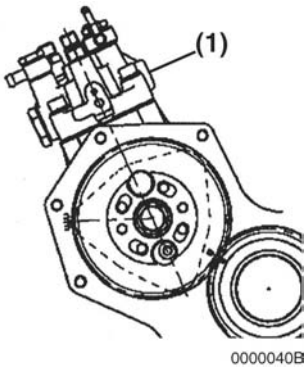


Figure7-33

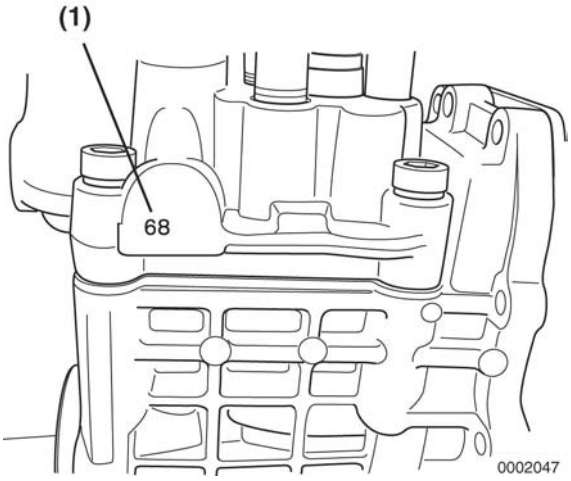


Figure7-34

2. Using the FIR number for the engine being serviced use the Fuel Injection Reference (FIR) Chart under “FIE Specs” on the Yanmar Distributor Website (http://distributor.yanmar.co.jp).
The FIR number is determined by the complete engine model number. The engine model number is located on the engine nameplate **(Figure 7-35)**.

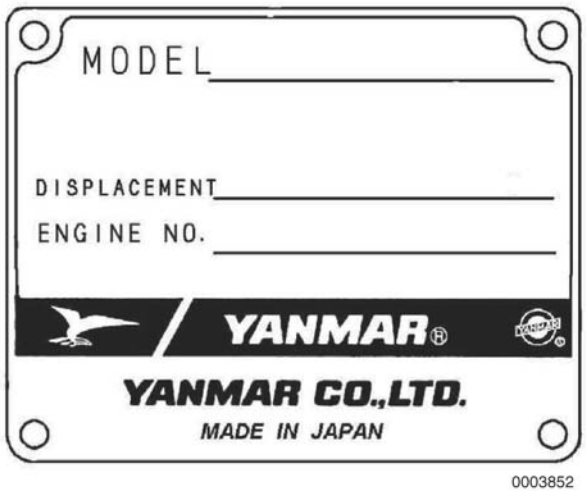


Figure7-35

EXAMPLE: The following example is for an engine model 4TNV98 - SDF.

- Find the engine model number in the FIR chart. Locate and record the FIR number (The FIR number for this engine is 4).

- Insert the numbers you have recorded into the following equation:
(Fuel Injection Pump Timing Index Number X 2) + FIR Number = FIT° (Fuel injection Timing in Degrees)

(6.8 X 2) = 13.6 + 4 = 17.6° Fuel injection Timing

- Record the calculated fuel injection timing specification.

Checking Fuel Injection Timing

NOTE: Some fuel may drain from the fuel injection pump during this process. Make provisions to contain any such spillage.

1. Turn off the fuel valve in the fuel supply hose and the fuel return hose.

2. Clamp shut the fuel injection pump fuel return hose leading to fuel filter **(Figure 7-36, (1)).**

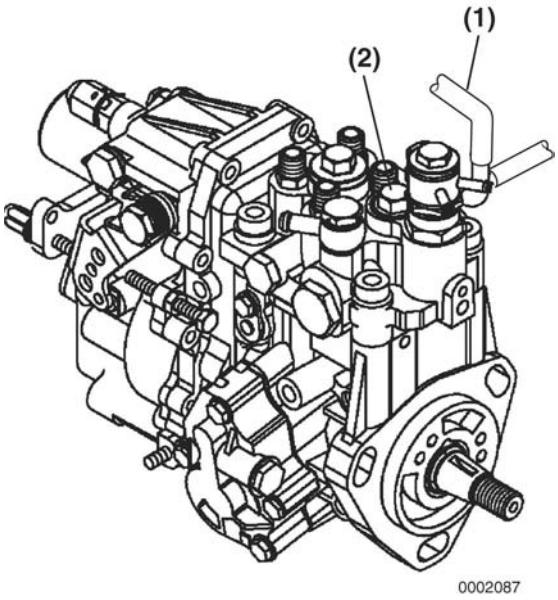


Figure 7-36

IMPORTANT

IMPORTANTClean the top of the fuel injection pump to prevent any contamination when the fuel injection pump plunger plug is removed.

3. Remove the forward fuel injection pump plunger plug **(Figure 7-36, (2))** on the top of the fuel injection pump.

4. Install a dial indicator adapter and clamp into the pump plunger opening.

NOTE: Use the Yanmar part no. 158090-51841 for the M16 adapter used on the MP4 fuel injection pumps (TNV94-106 model engines) and Yanmar part no. 23000-013000 plunger adapter clamp **(Figure 7-37, (1))**.

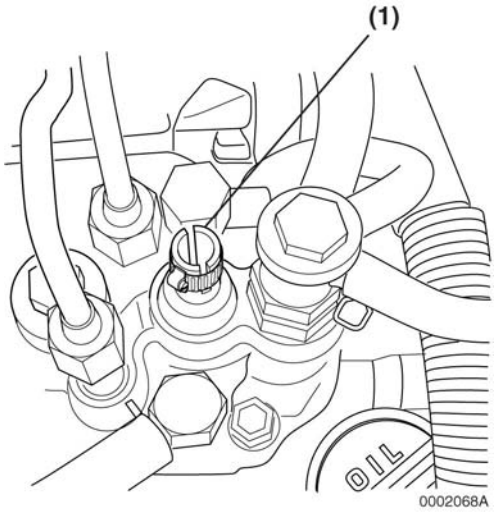


Figure 7-37

5. Install a dial indicator **(Figure 7-38, (1))**, Mitutoyo No. 2050SB or equivalent, with a 30mm extension, Yanmar part no. 158090-51870 or Mitutoyo No. 303613, into the adapter. Secure with the Yanmar part no. 23000-013000 plunger adapter clamp **(Figure 7-37, (1))** at approximately the mid-point of its travel.

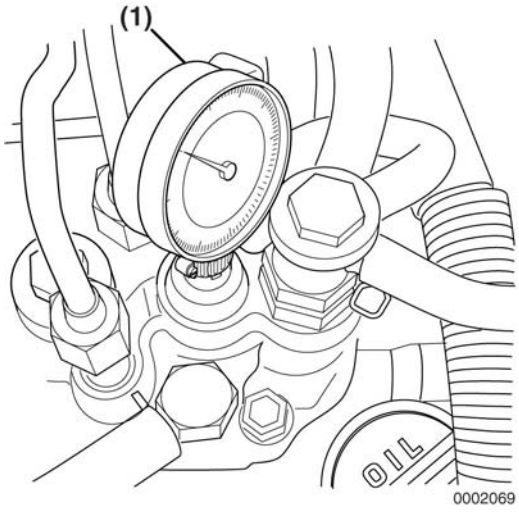


Figure 7-38

NOTE: The following references to the direction-of-rotation are facing the coolant pump end of the engine and are adjusted by turning the crankshaft pulley.

6. Using a wrench on the crankshaft pulley bolt, rotate the crankshaft in a clockwise direction while looking through the flywheel inspection port **(Figure7-39, (1))**. Rotate the crankshaft until the injection timing marks on the flywheel are visible.

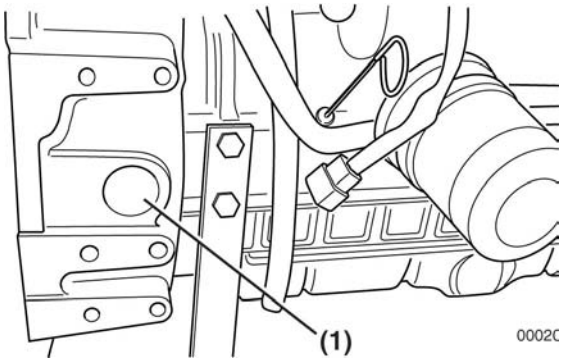


Figure 7-39

7. Typical flywheel markings are as shown in **(Figure 7-40, (1))**.

NOTE: A typical flywheel will have multiple timing grids depending on the number of cylinders. Any grid can be used to check the fuel injection timing.

The flywheel shown in Figure 7-40 is for a Yanmar “Standard Specification” DI engine. Flywheels used on some “OEM Specific” DI engines may be marked differently. You should contact that specific OEM for information on the identification of the timing marks.

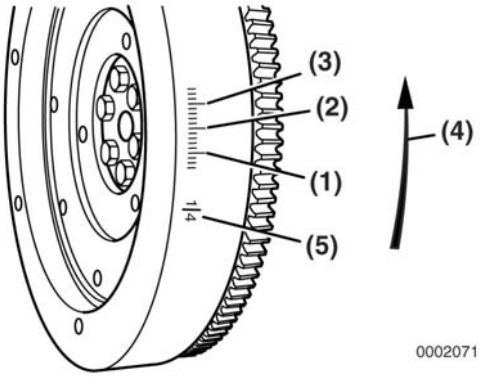


Figure 7-40

(1) 10° BTDC (Before Top Dead Center) (2) 15° BTDC.
(3) 20° BTDC (4) Direction of Rotation.
(5) TDC (Top Dead Center)

NOTE: The TDC (Top Dead Center) mark can be identified by the cylinder numbers stamped near the TDC mark on the flywheel.

If you are uncertain as to the timing degree designation of the timing marks on the flywheel timing grid, you can determine the timing degree designation by measuring the timing grid.

- First measure the distance between two of the “longer” marks on the timing grid. (They are 5° apart.) Then measure the distance from the TDC mark to the first “longer” mark on the timing grid. Divide that measurement by the distance between the two “longer” marks. The resulting answer will tell you how many degrees there are between the TDC mark and the first “longer” mark.

- EXAMPLE: If the distance between the two “longer” marks is approximately 2.0 cm and the distance from the TDC mark is approximately 4.0cm, the answer is approximately 2. This indicates there is 10° (2x5°) between the TDC mark and the first “longer” mark on the timing grid. That means the first “longer” mark on the timing grid indicates 10° BTDC, the second “longer” mark indicates 15° BTDC and the third timing mark indicates 20° BTDC. If the answer is 3, that indicates there is 15° (3x15°) between the TDC mark and the first “longer” mark and that the first “longer” mark indicates 15° BTDC with the second and third “longer” marks indicating 20° BTDC and 25° BTDC respectively.

8. Highlight the timing reference mark **(Figure 7-41, (2))** on the flywheel housing or engine back plate **(Figure 7-42, (2))**. Highlight the TDC (Top Dead Center) mark **(Figure 7-41, (1))** on the flywheel.

9. Highlight the target timing mark **(Figure 7-42, (1))** on the flywheel as calculated in Determining the Fuel Injection Timing Specification on page 141.

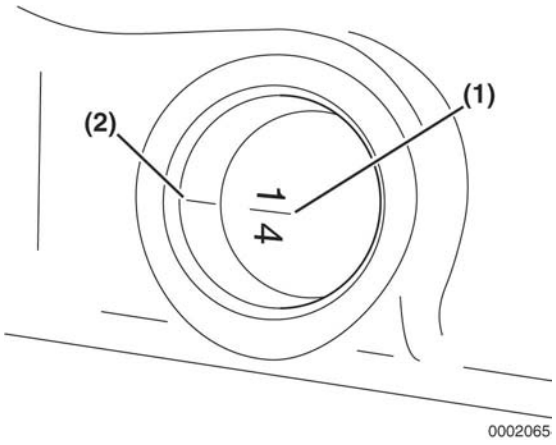
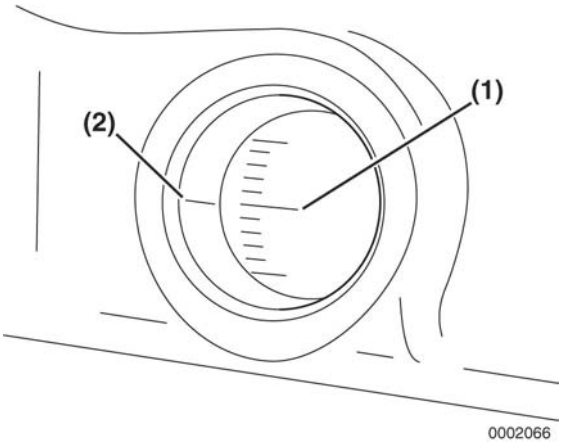


Figure 7-41



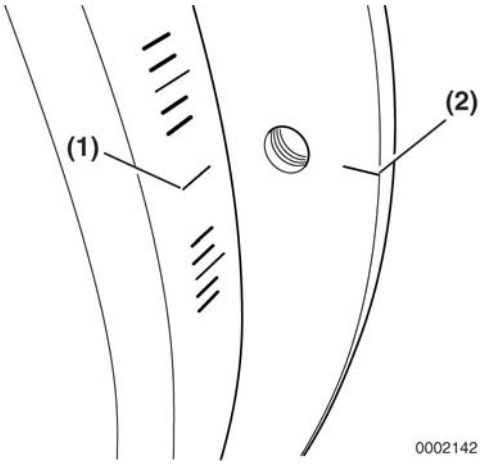


Figure 7-42

10. Rotate the crankshaft counter-clockwise until the dial indicator shows that the injection pump plunger is at the bottom of its stroke. Rock the crankshaft back and forth slightly to confirm a point where the dial indicator shows no movement. Zero the dial indicator.

11. Slowly rotate the crankshaft clockwise until the dial indicator shows a pump plunger lift of 2.5mm (0.098 in.).

12. Check the position of the flywheel target timing mark (previously determined) **(Figure7-42, (1))** in relation to the timing reference mark **(Figure7-42, (2))** on the flywheel housing or engine back plate. If the two marks are aligned, the fuel injection timing is correct. If the marks do not align, the fuel injection timing must be adjusted. See Adjusting Fuel Injection Timing on page 161.

13. If the injection timing is correct, remove the dial indicator and adapter. Replace the pump plunger plug and its copper gasket and tighten to specifications. Replace the flywheel inspection port cover. Open the fuel supply valve and remove the clamp from the fuel supply hose and the fuel return hose.

14. Prime the fuel system. Operate the engine and check for leaks.

Adjusting Fuel Injection Timing

If the timing marks did not align when performing the Checking Fuel Injection Timing on page 158, the following steps must be performed to properly time the engine.

1. Leave the dial indicator installed in the fuel injection pump. Do not disturb the reading on the dial indicator.

2. Rotate the flywheel until the target timing mark **(Figure7-43, (1))** and the timing reference mark **(Figure7-43, (2))** on the flywheel housing or back plate are aligned.

IMPORTANT

Do not rotate the crankshaft during the remainder of this procedure.

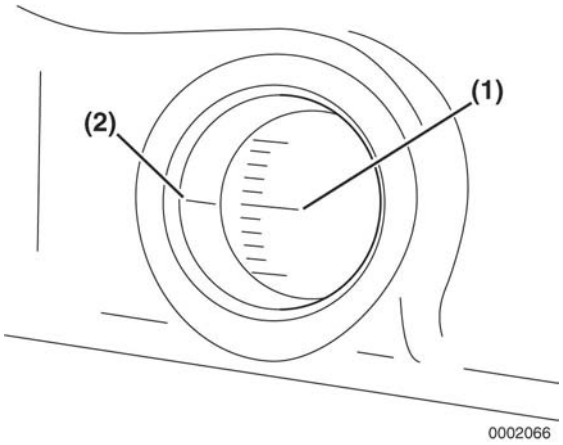


Figure 7-43

3. Note the reading on the dial indicator **(Figure 7-44, (1))**. If the reading is less than 2.5mm (0.098 in.), the fuel injection timing is “retarded.” If the dial indicator reading is greater than 2.5mm (0.098 in.), the fuel injection timing is “advanced.”

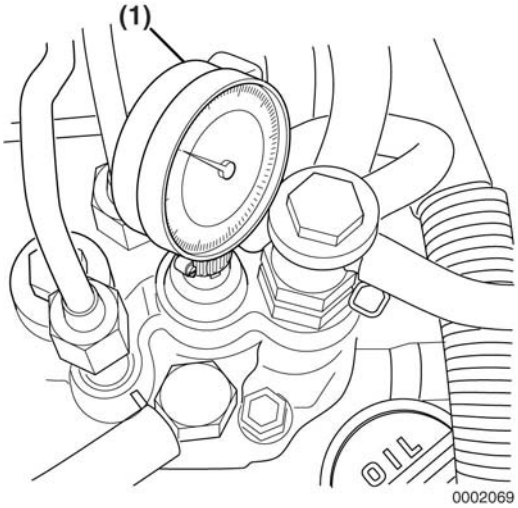


Figure 7-44

NOTE: Some model engines require the intake manifold and fuel injection pump insulator be removed to access the inner fuel injection pump retaining nuts.

4. Loosen the nuts fastening the fuel injection pump to the gear case or front plate. Loosen the rear bracket(s) on the fuel injection pump.

NOTE: Loosening the high-pressure injection line nuts on the fuel injection pump may make rotating the pump easier.

5. Rotate the fuel injection pump until the dial indicator reads 2.5 mm (0.098 in.).

6. To “advance” the injection timing, rotate the top of the fuel injection pump away from the engine.

7. To “retard” the injection timing, rotate the top of the fuel injection pump toward the engine.

8. When the dial indicator reads 2.5 mm (0.098in.) of pump plunger lift and the target timing mark on the flywheel aligns with the reference mark on the flywheel housing or engine back plate, the injection timing is correct.

9. Tighten the fuel injection pump mounting nuts and rear bracket(s).

10. Remove the dial indicator and adapter. Replace the plug in the pump plunger opening and tighten it to specification. If removed, install the intake manifold and pump insulator. Tighten the high-pressure injection line nuts to specification. Open the fuel supply valve, remove the clamp from the fuel return line and prime the fuel system. Operate the engine and check it for leaks.

Fuel Injectors

Removal of Fuel Injectors

4-Valve Cylinder Head

1. Close any fuel valves in the fuel supply line.

2. Remove the valve cover.

3. Remove the injector return line **(Figure7-48, (1))**. Be careful not to bend the line.

4. Remove the fuel injector mounting clamp bolts **(Figure7-48, (2))**. Lift the injector mounting clamps **(Figure7-48, (3))** away from injector.

5. Remove the fuel injector **(Figure7-48, (4))** from the cylinder head.

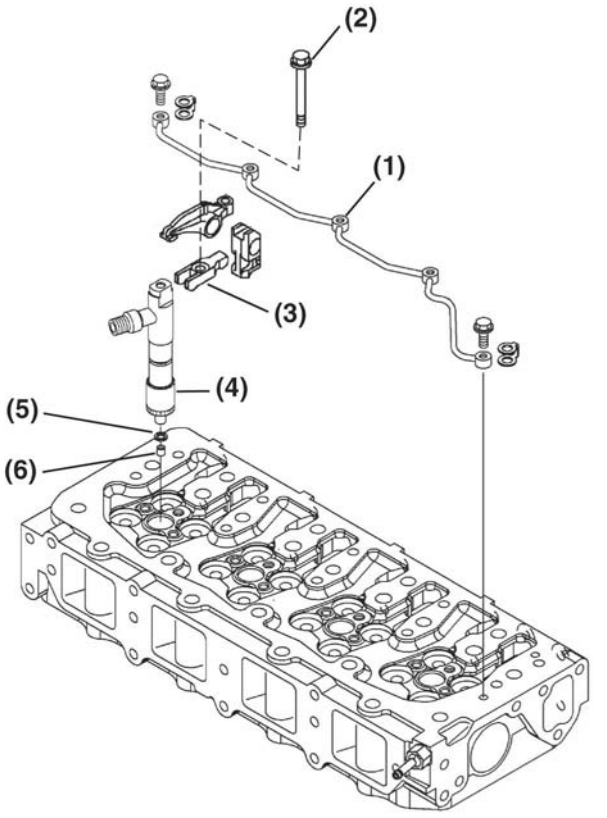


Figure 7-48

NOTE: The fuel injectors can be removed by manually pulling them out of the fuel injector wells.

6. Remove the injector nozzle protector **(Figure 7-48, (5))** and seat **(Figure 7-48, (6))** from the cylinder head. Discard both items.

7. Repeat steps to remove the remaining fuel injectors.

Testing of Fuel Injectors

CAUTION

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Thoroughly clean the fuel injector nozzle using clean diesel fuel and a brass wire brush.

2. Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean, repair or replace as necessary.

NOTE: Test the fuel injector using an injection nozzle tester. Operate the tester following the information provided by the tester manufacturer. Use clean, filtered fuel or FIE calibration fluid for the test.

3. Using the correct adapter, connect a fuel injector to a nozzle tester. Aim the fuel injector into a suitable container to catch the fuel spray.

⚠ WARNING

Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

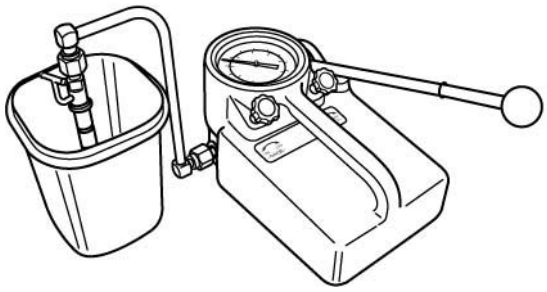


Figure 7-49

4. Pump the operating lever of the tester slowly, observing the pressure reading at the point where the fuel injector begins spraying fuel **(Figure 7-49).**
See **Figure 7-52** for injector ID location.

See Test and Adjustment Specifications on page 7-9 for correct pressure readings.

NOTE: The opening pressure of a new fuel injector will be approximately 725 psi (5MPa; 51kgf/cm²) higher than one that has been operated for five hours or longer.

5. Pump the operating lever slowly to hold the pressure steady at a point just below the opening pressure and hold it for 5 seconds. Observe the injector to see that it is sealing properly and is not “dripping”. If fuel leaks from the return line fitting, check that the nozzle case nut is tight. Service or replace the injector if fuel continues to leak from either the return line fitting or nozzle.

6. Pump the operating lever more rapidly to repeatedly “pop” the injector and observe the spray pattern. The pattern should be a very fine uniform spray **(Figure 7-50)**. If a dripping or an uneven pattern is seen **(Figure 7-51)**, service or replace the injector.

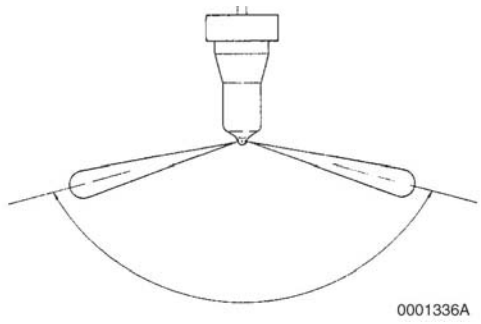


Figure 7-50

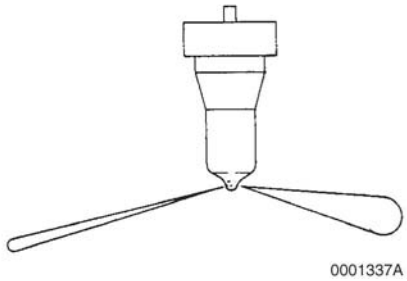


Figure7-51

If the fuel injector fails any of these tests, it should be serviced or replaced as necessary. If the pressure is outside specified limits, adjust the pressure. See Adjusting Fuel Injector Pressure on page 166.

Disassembly and Inspection of Fuel Injectors

CAUTION

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Clean carbon from used injectors using clean diesel fuel. Hardened deposits or varnish can be cleaned using a brass wire brush.

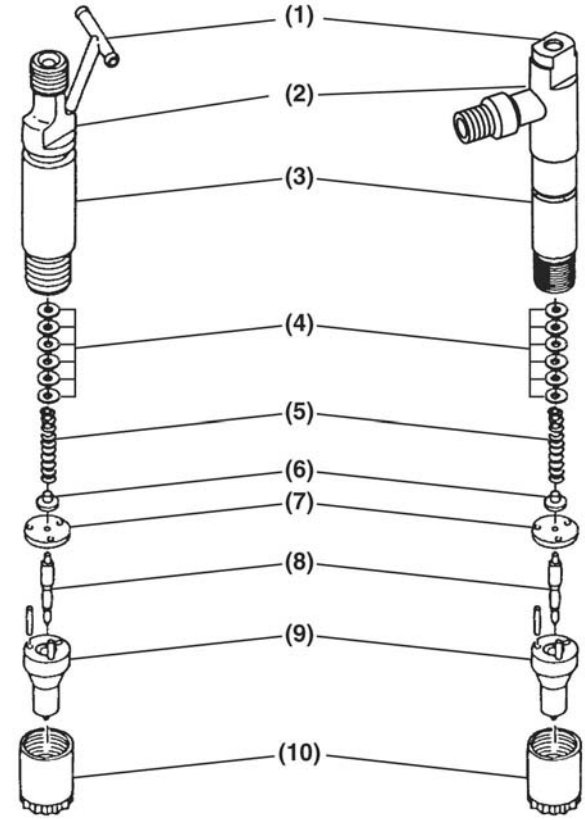


Figure 7-52

(1) Fuel Return Passage. (2) Injector ID Location.
(3) Injector Body. (4) Pressure Adjusting Shims. (5) Spring.
(6) Spring Seat. (7) Valve Stop Spacer. (8) Nozzle Valve.
(9) Nozzle Body. (10) Nozzle Case Nut

2. Place the fuel injector in a soft-jawed vise with the nozzle pointing up.

3. Remove the nozzle case nut.

4. Carefully remove the injector from the vise.

5. Turn the injector over and remove the nozzle body, nozzle valve, valve stop spacer, nozzle spring seat, nozzle spring, and shims.

6. Inspect the sealing surfaces **(Figure 7-53, (2))** between the valve stop spacer and nozzle body for nicks or scratches. Check the contact area between the valve stop spacer and the nozzle valve **(Figure 7-53, (1))** for scoring, or pitting. Use a magnifier glass to inspect the area.

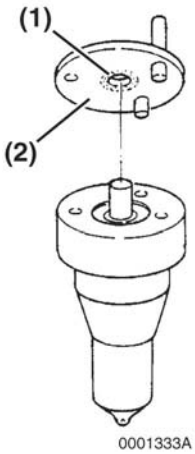


Figure 7-53

7. Perform a nozzle valve slide test:

(a) Wash nozzle body and valve in clean diesel fuel.
(b) While holding the nozzle body vertical, pull the nozzle valve about 2/3 of the way out **(Figure 7-54)**.
(c) Release the valve. It should fall smoothly to its seat by it's own weight.

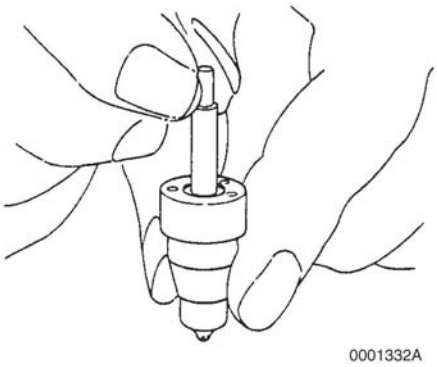


Figure 7-54

8. Replace the fuel injector assembly if it fails any inspection.

Adjusting Fuel Injector Pressure

The fuel injectors open when pressure reaches a predetermined pressure threshold. They close when the pressure is reduced below that threshold. The pressure threshold can be adjusted by adding or removing shims **(Figure 7-55, (3))**.

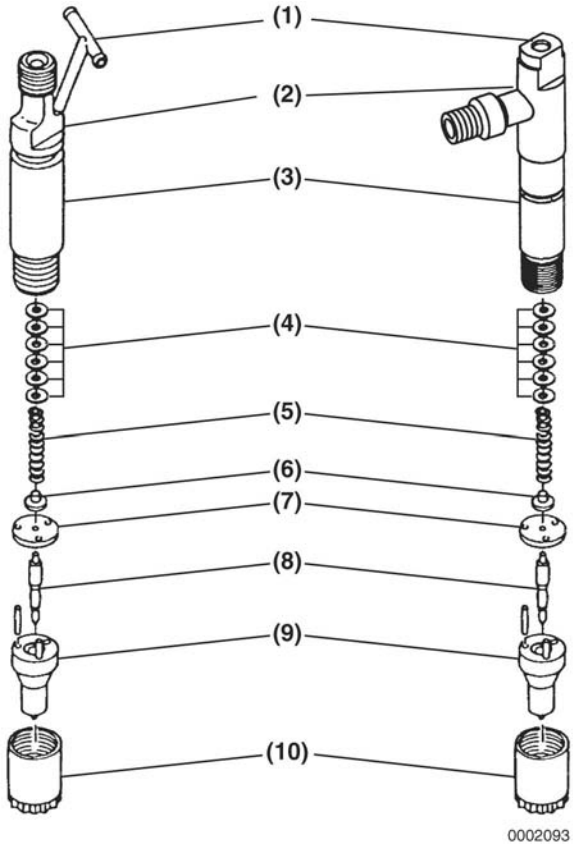


Figure 7-55

(1) Fuel Return Passage. (2) Injector ID Location.
(3) Injector Body. (4) Pressure Adjusting Shims. (5) Spring.
(6) Spring Seat. (7) Valve Stop Spacer. (8) Nozzle Valve.
(9) Nozzle Body. (10) Nozzle Case Nut.

The injection pressure will change by approximately 275 psi (1.9 MPa; 19 kgf/cm^2) for every 0.1 mm (0.004 in.) in shim thickness.

See the parts catalog for available shims.

CAUTION

Each pressure adjusting shim removed or added changes the pressure threshold by approximately 275 psi (1.9 MPa, 19 kgf / cm²). Adding adjusting shims increases the threshold pressure. Removing adjusting shims reduces the pressure threshold.

1. Disassemble the fuel injector assembly. See Disassembly and Inspection of Fuel Injectors on page 165.

2. Remove or add adjusting shims as needed.

3. Reassemble the fuel injector assembly. See Reassembly of Fuel Injectors on page 166.

4. Retest the fuel injector. See Testing of Fuel Injectors on page 164. If the injector cannot be adjusted to the appropriate pressure, discard the fuel injector.

Reassembly of Fuel Injectors

1. Secure the injector in a soft-jawed vise with the nozzle end up.

2. Reinstall the shims, nozzle spring, nozzle spring seat, valve stop spacer, nozzle valve, and nozzle body.

3. Reinstall the nozzle case nut. Tighten it to specification. See Special Torque Chart on page 143.

Installation of the Fuel Injectors

4-Valve Cylinder Head

1. Reinsert a new nozzle seat **(Figure 7-57, (6))** and nozzle protector **(Figure 7-57, (5))** in the cylinder head for each injector.

2. Reinstall a O-ring on to each injector body.

3. Reinsert each fuel injector **(Figure 7-57, (4))** into the cylinder head.

4. Reinstall the fuel injector retainers **(Figure 7-57, (3))** and torque the retaining bolts **(Figure 7-57, (2))** to specification.

5. Reinstall the fuel injector return line assembly using new gaskets on each side of the injector line screws.

6. Reinstall the fuel high-pressure fuel lines to each injector and tighten the nuts using a “line” or “flare nut” wrench.

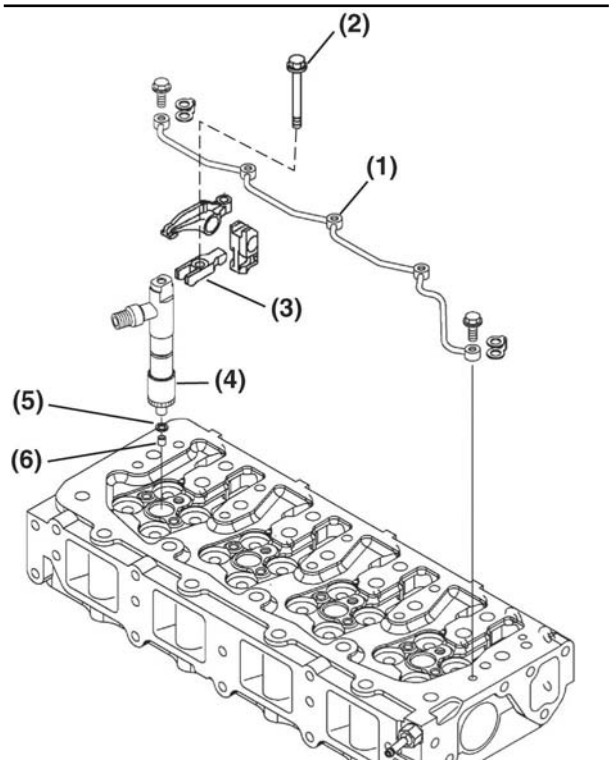


Figure 7-57

7. Prime the fuel system. See Priming the Fuel System on page 15.

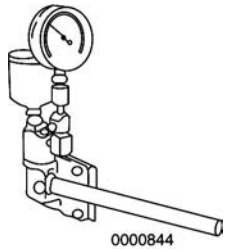
8. Operate the engine and check for fuel and coolant leaks.

4TNE98 ENGINE

Fuel System Special Torque Chart

Component	Tightening Torque	Lubricating Oil Application (Thread Portion and Seat Surface)	Reference Page
Fuel Injector	29.4 ft·lbs (39.2 N·m, 4 kgf·m)	Not Applied	See Installation of Fuel Injectorson page 200
Fuel Pump Drive Gear Nut	43.5 - 51.0 ft·lbs (59 - 69 N·m, 6.0 - 7.0 kgf·m)	Not Applied	See Installation of the Fuel Injection Pumpon page 192

Measuring Instruments

No.	Tool Name	Application	Illustration
1	Fuel Injector Tester	For measuring injection spray pattern of fuel injection nozzle and injection pressure	 0000844

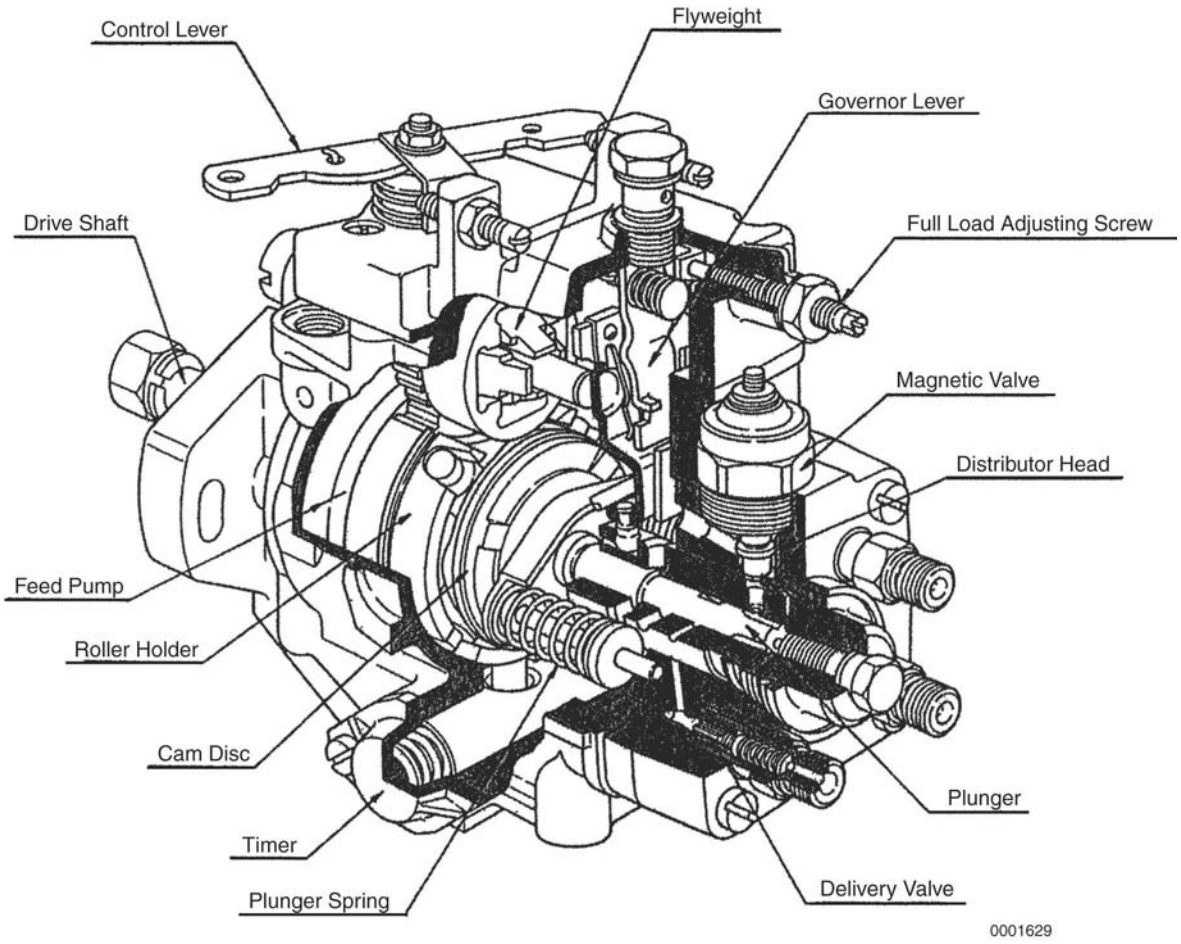

Control Lever
Flyweight
Governor Lever
Drive Shaft
Full Load Adjusting Screw
Magnetic Valve
Distributor Head
Feed Pump
Roller Holder
Cam Disc
Plunger
Timer
Plunger Spring
Delivery Valve
0001629

Figure 7-1

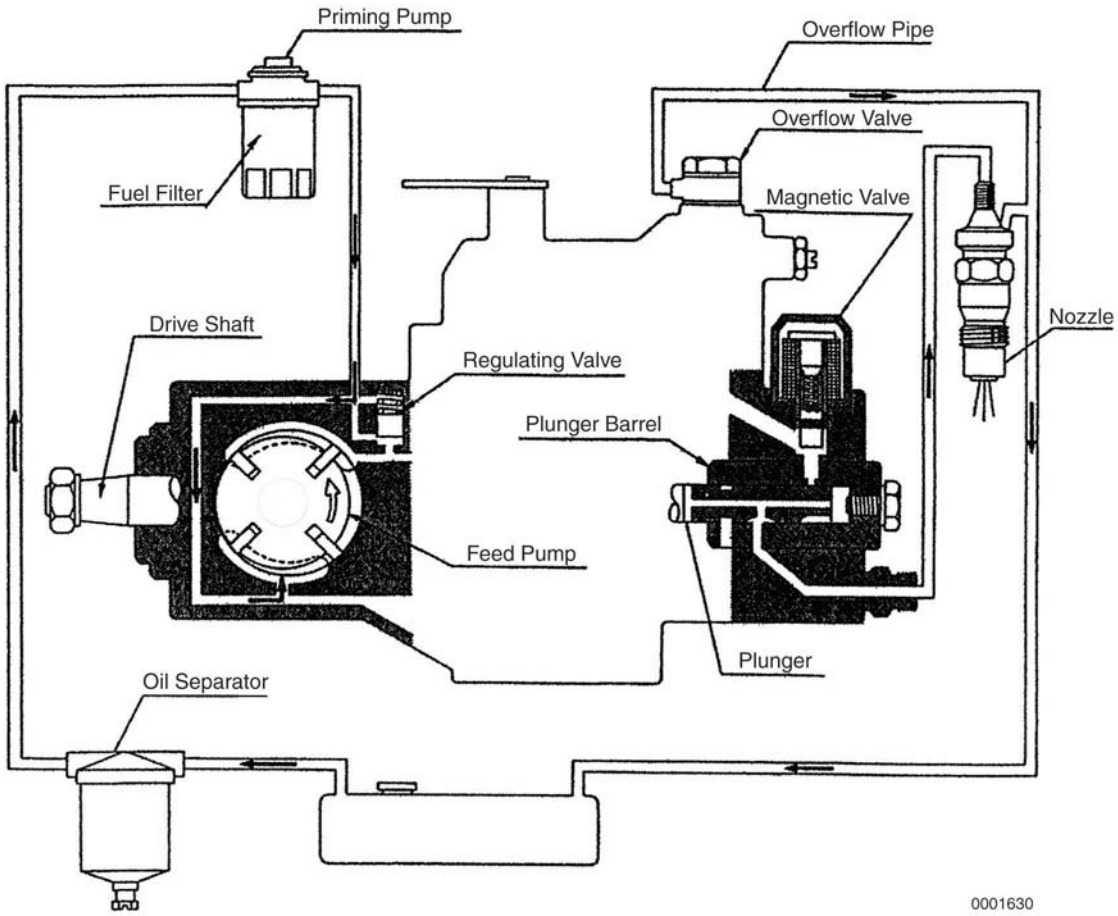


Figure 7-2

Fuel is fed from the fuel tank into the fuel inlet of the injection pump by the feed pump built into the injection pump via the oil separator and fuel filter.

A filter is installed for fuel filtration. A filter with an oil separator for water separation is also provided at the bottom.

Pressure is applied to feed fuel into the fuel inlet by the feed pump in order to feed fuel into the injection pump chamber.

Although the fuel pressure in the pump chamber is proportional to the pump revolution, excessive fuel is returned to the suction system by the regulating valve when the pressure exceeds the specified value. The fuel is then sent to the plunger via the fuel path in the distributor head. The plunger applies high pressure to the fuel to feed it to the nozzle and nozzle holder through the injection pipe.

The overflow valve above the injection pump functions to maintain constant fuel temperature in the pump chamber and return excessive fuel to the fuel tank.

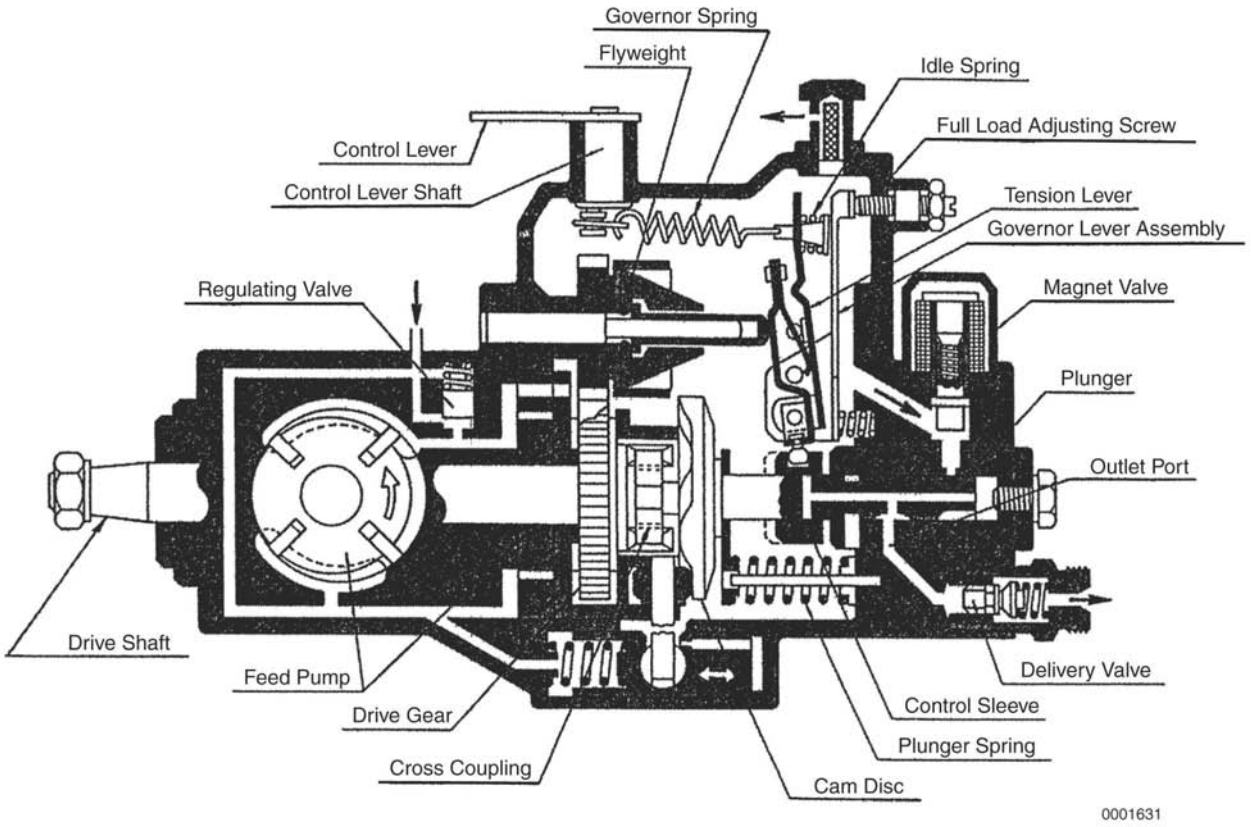

Governor Spring
Flyweight
Idle Spring
Full Load Adjusting Screw
Control Lever
Control Lever Shaft
Tension Lever
Governor Lever Assembly
Regulating Valve
Magnet Valve
Plunger
Outlet Port
Drive Shaft
Feed Pump
Drive Gear
Cross Coupling
Delivery Valve
Control Sleeve
Plunger Spring
Cam Disc
0001631

Figure 7-3

Overview

Pump

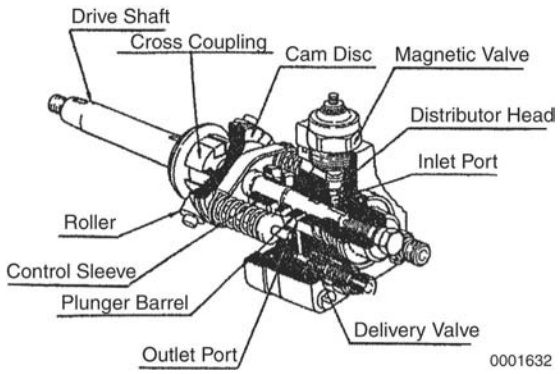


Figure 7-4

The drive shaft directly receives the engine revolution via the timing belt (or gear) and transfers it to the cam disc via the cross coupling. Since the dowel pin of the cam disc is integrated with the plunger and fixed in the groove in the plunger collar, the plunger operates at the same speed as the cam disc.

The cam disc has a face cam and conducts reciprocating operations by the specified cam lift on the roller in the roller holder assembly.

On the outside of the plunger are two plunger springs having the settling force to return the plunger lifted by the cam disc during the lowering process. Thus, the plunger revolves by means of the drive shaft and the reciprocates by means of the cam disc. When the fuel fed under high pressure by the plunger reaches the outlet port, the delivery valve opens to inject it into the engine combustion chamber via the nozzle and nozzle holder.

Governor

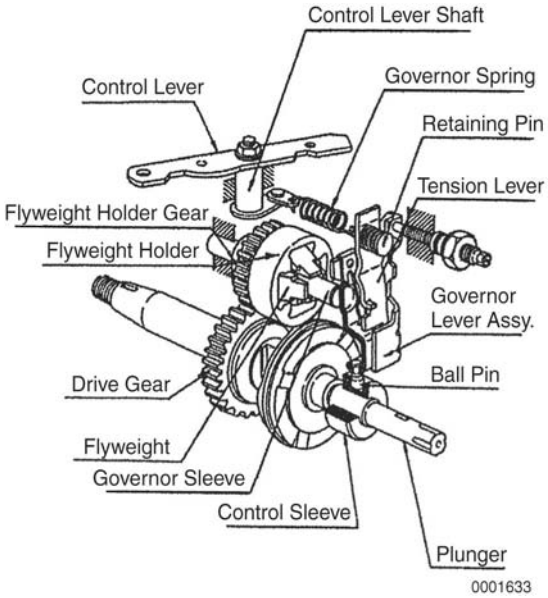


Figure 7-5

The governor is located above the inspection pump chamber and mainly consists of a flyweight holder and governor lever assembly. The flyweight holder holds four flyweights and governor sleeves, and is supported by the governor shaft.

The drive gear engages with the flyweight holder gear to increase the revolutions of the drive shaft and to turn the flyweight holder assembly. The governor lever assembly is secured by the pivot bolt of the pump housing and the ball pin at the bottom of the assembly is inserted into the control sleeve which slides on the outer periphery of the plunger. The governor spring at the top of the assembly is connected to the tension lever by the retaining pin. The end of the governor spring is connected to the control lever via the control lever shaft. The control lever is linked to the acceleration pedal via the link to change the set force of the governor spring according to the inclined angle. The difference between the governor spring set force and the flyweight centrifugal force determines the moving distance of the control sleeve, thereby increasing or decreasing the fuel injection volume.

Timer

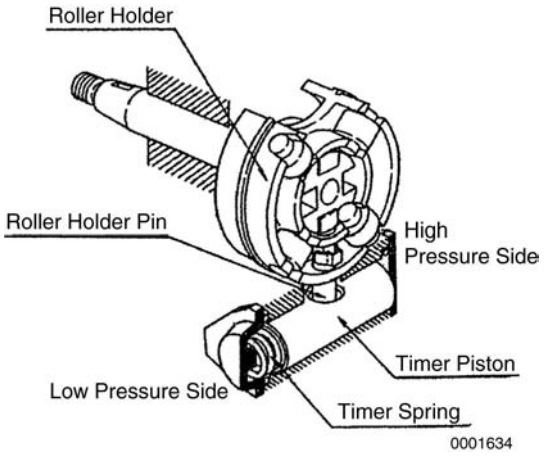


Figure 7-6

At the bottom of the injection pump is the built-in timer. A timer spring having a set force is installed on the low pressure side of the timer piston. The fuel pressure in the pump chamber is directly applied to the other end (high pressure side) of the timer piston. The position of the timer piston changes according to the balance between the fuel pressure and the timer spring force to turn the roller holder via the roller holder pin. When the piston moves in the direction to compress the timer spring, the roller holder moves in the advance direction (counter-revolution direction) to early the injection timing. Thus, the timer controls the fuel injection timing according to the fuel pressure in the pump chamber.

Feed Pump (Vane Type)

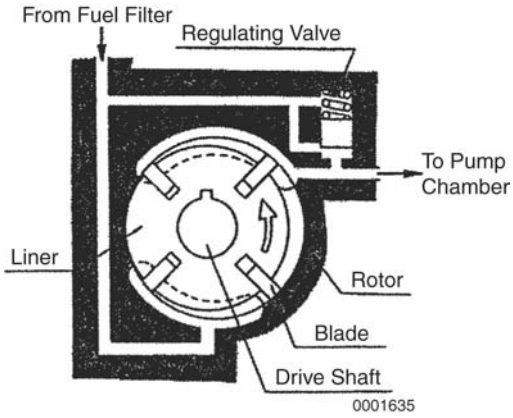


Figure 7-7

The feed pump functions to feed fuel from the fuel tank to the pump chamber.

The feed pump consists of the rotor, blade (vane) and liner. The rotor is driven by the drive shaft. The liner is located eccentrically to the center of the rotor and four blades (vanes) are located between the rotor and liner. When the rotor turns, the blades are pressed onto the liner inner wall by centrifugal force to change the capacity of the chambers according to the revolutions. When the capacity of a chamber increases, it draws fuel from the fuel tank.

When the capacity decreases, it feeds fuel into the pump chamber.

Regulating Valve

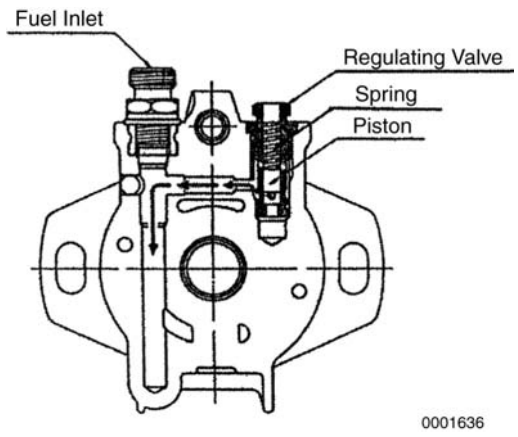


Figure 7-8

The regulating valve regulates the fuel feeding pressure of the feed pump so that the fuel pressure in the pump chamber is maintained within the specified pressure range.

When the injection pump revolutions increase to increase the fuel feeding pressure of the feed pump, the fuel compresses the regulating valve spring to lift the piston. The fuel is then returned to the suction side as shown by the arrow in the figure.

It is therefore possible to regulate the pump chamber pressure by changing the set force of the regulating valve spring.

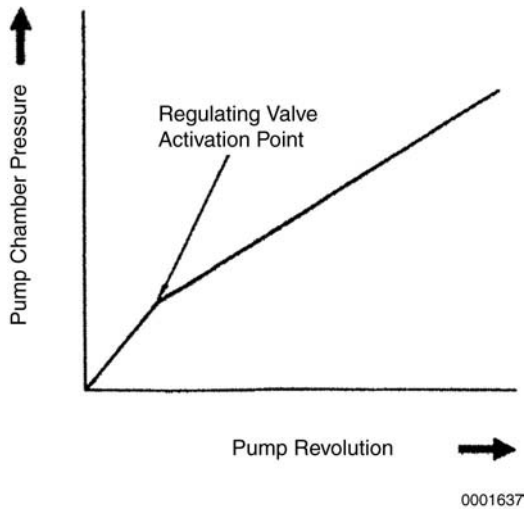


Figure 7-9

Figure 7-9 shows typical relationships between pump revolutions and pump chamber pressure. The hydraulic timer directly uses the pump chamber pressure for controlling the injection timing.

Plunger Operation

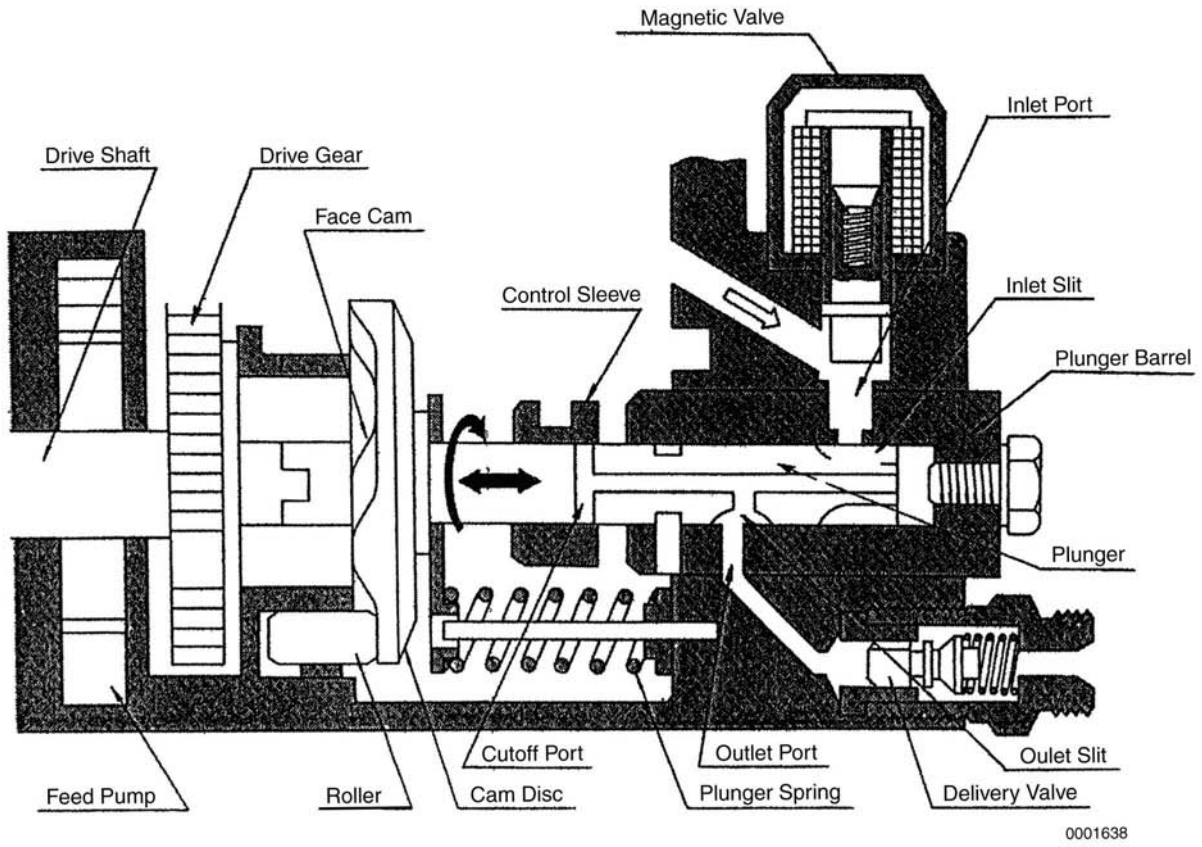


Figure 7-3

The drive shaft simultaneously drives the feed pump, cam disc and plunger. The plunger spring presses the plunger and cam disc onto the roller. When the cam disc turns by means of the drive shaft, the face cam moves on the roller to activate the plunger's reciprocating operation. When the inlet port of the plunger barrel being pressed into the distributor head and the inlet slit of the plunger overlap, the plunger draws fuel and applies pressure to it.

When the outlet port of the plunger barrel and the outlet slit of the plunger align, the high-pressure fuel opens the delivery valve to be injected into the engine combustion chamber via the nozzle. When the cutoff port reaches the control sleeve, pressure feeding from the plunger is terminated.

Process

Suction Process

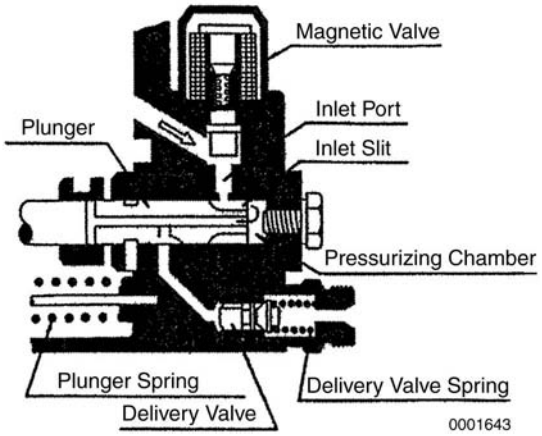


Figure 7-10

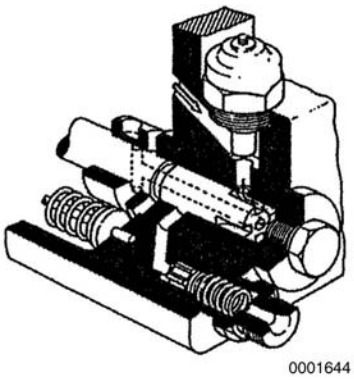


Figure 7-11

When the inlet port of the plunger barrel overlaps the inlet slit of the plunger during the lowering process of the plunger, the fuel in the pump chamber is drawn into the plunger.

Injection Process

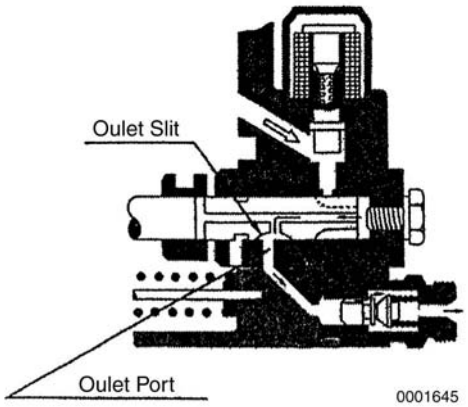


Figure 7-12

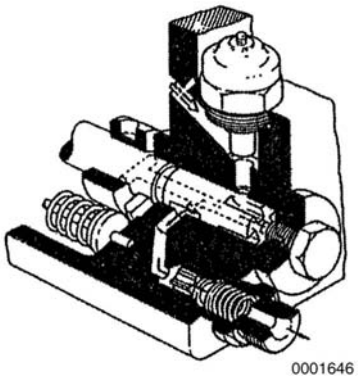


Figure 7-13

The plunger begins rotating at the same time the lifting process of the cam disc begins. When the inlet port of the plunger barrel is covered by the plunger, pressure feeding of fuel is initiated. At the same time, the highly pressurized fuel presses up the delivery valve when the outlet slit of the plunger meets the outlet port of the plunger barrel. The fuel is then injected into the engine combustion chamber via the nozzle and nozzle holder.

End of Injection

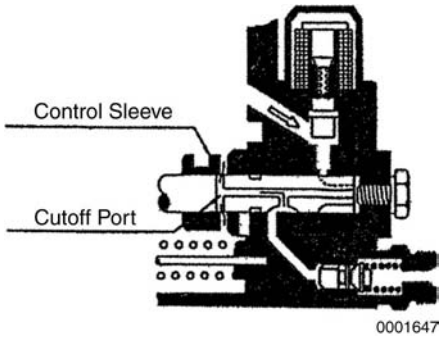


Figure 7-14

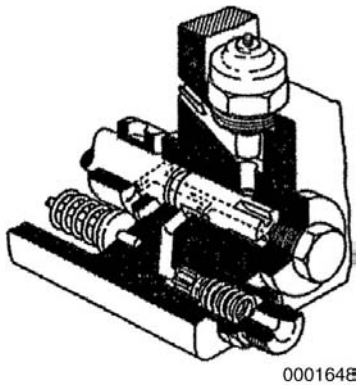


Figure 7-15

When the plunger is further lifted up by the cam disc until the cutoff port of the plunger just overruns the control sleeve, the high-pressure fuel in the plunger high-pressure chamber returns to the pump chamber through the cutoff port. As a result, the fuel pressure in the plunger becomes lower than the set force of the delivery valve spring, so, the delivery valve closes to terminate pressure feeding of fuel.

Uniform Pressure Process

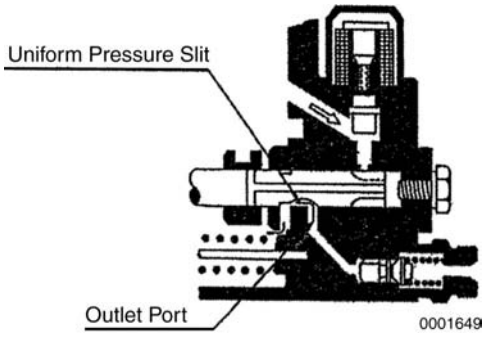


Figure 7-16

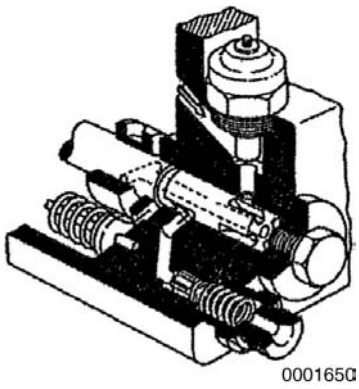


Figure 7-17

When the plunger turns a further 180° after the end of fuel injection, the uniform pressure slit of the plunger meets the outlet port of the plunger barrel. As a result, the pump chamber is connected to the outlet port, thereby making the pressure in the chamber and outlet port equal. After the uniform pressure process, the pressure in the outlet port becomes uniform, ensuring stable fuel injection.

The suction process through the uniform pressure process are carried out for each cylinder during every injection cycle.

Reverse Rotation Prevention Mechanism

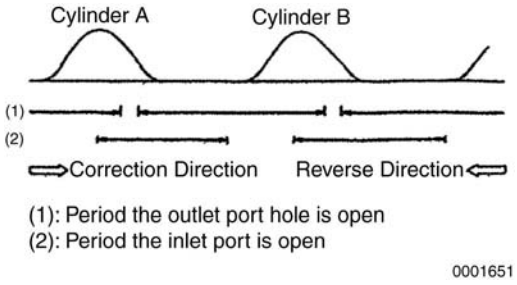


Figure 7-18

While the plunger is rotating in the correct direction, the fuel is sufficiently drawn into the plunger since the inlet port of the plunger barrel opens during the plunger lowering process. The inlet port closes during the lifting process to inject the fuel.

On the contrary, the inlet port of the plunger barrel does not close during the plunger lifting process if the engine rotates in the reverse direction. So, the fuel is not pressurized, resulting in non-injection state.

Fuel Injection Volume Adjustment Mechanism

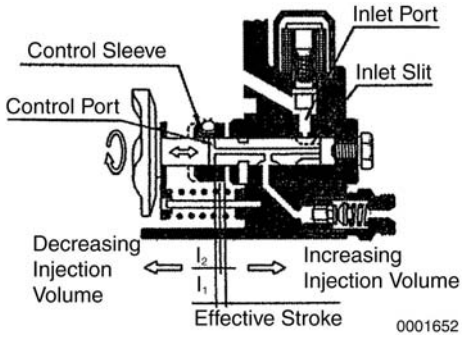


Figure 7-19

The fuel injection volume is increased or decreased by changing the control sleeve position, resulting in change of the effective stroke. The effective stroke represents the plunger's stroke from the time the inlet port and inlet slit close until the cutoff port overruns the control sleeve, which is proportional to the fuel injection volume. When the control sleeve moves to the left, the effective stroke (I_2) decreases. When the control sleeve moves in the opposite direction, or to the right, the effective stroke (I_1) increases to increase the fuel injection volume. The control sleeve position is determined according to the governor control.

Delivery Valve Assembly

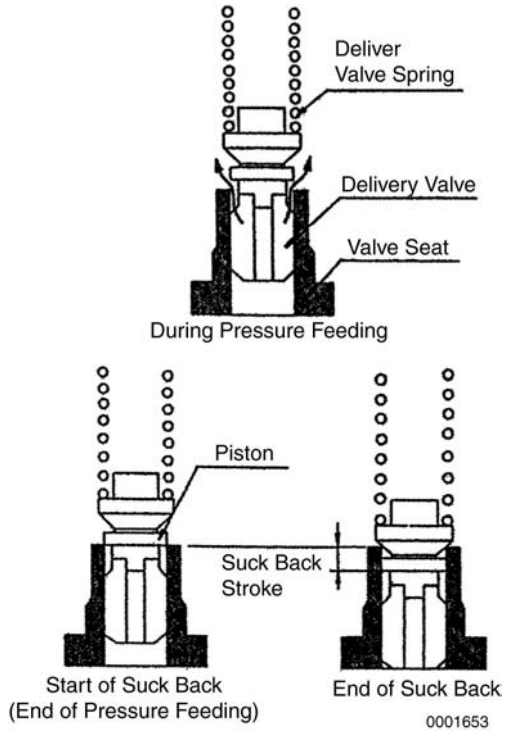


Figure 7-20

The delivery valve assembly consists of the delivery valve and valve seat.

When the pressure of the high-pressure fuel being fed from the plunger exceeds the force of the delivery valve spring, the delivery valve opens to feed the high-pressure fuel to the nozzle and nozzle holder via the injection pipe. After injection, a certain degree of remaining pressure exists in the injection pipe ready for the next injection. The delivery valve prevents the fuel remaining in the injection pile from returning to the plunger.

If the remaining pressure is excessively high, cutoff of the fuel may be adversely affected.

The delivery valve also functions to improve fuel cutoff of the nozzle by drawing back the fuel in the pipe by the amount equal to the suck-back stroke of the piston.

Delivery Valve Holder with Damping Valve

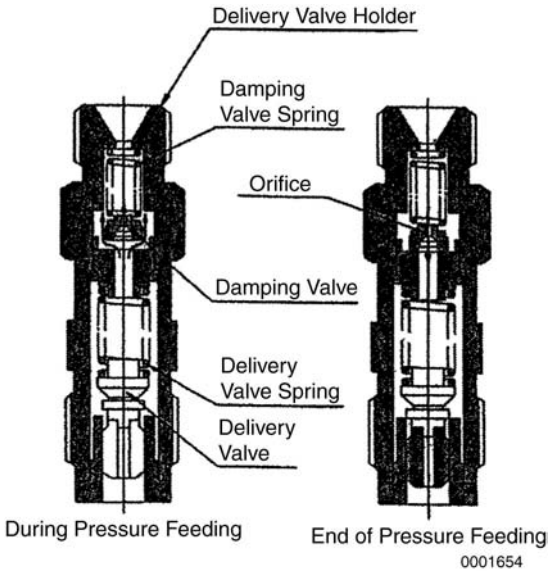


Figure 7-21

The delivery valve holder with damping valve functions to prevent cavitation erosion in the pipe at high speed, unstable fuel injection and secondary injection.

When high-pressure fuel is fed from the plunger, it is mainly sent to the nozzle through the outer periphery of the damping valve since the damping valve also opens at the same time as the delivery valve upon completion of each injection cycle.

So, the only fuel path left is the small orifice of the damping valve. This permits the slow closing of the delivery valve. Thus, rapid pressure decrease in the pipe is prevented and transfer of the reflection wave in the pipe suppressed to ensure stable injection.

NOTE: Cavitation represents the phenomenon where bubbles are generated in the pipe when the pressure in the pipe drops. Cavitation erosion means erosion of the pipe inner wall as a result of cavitation.

All - Speed Governor

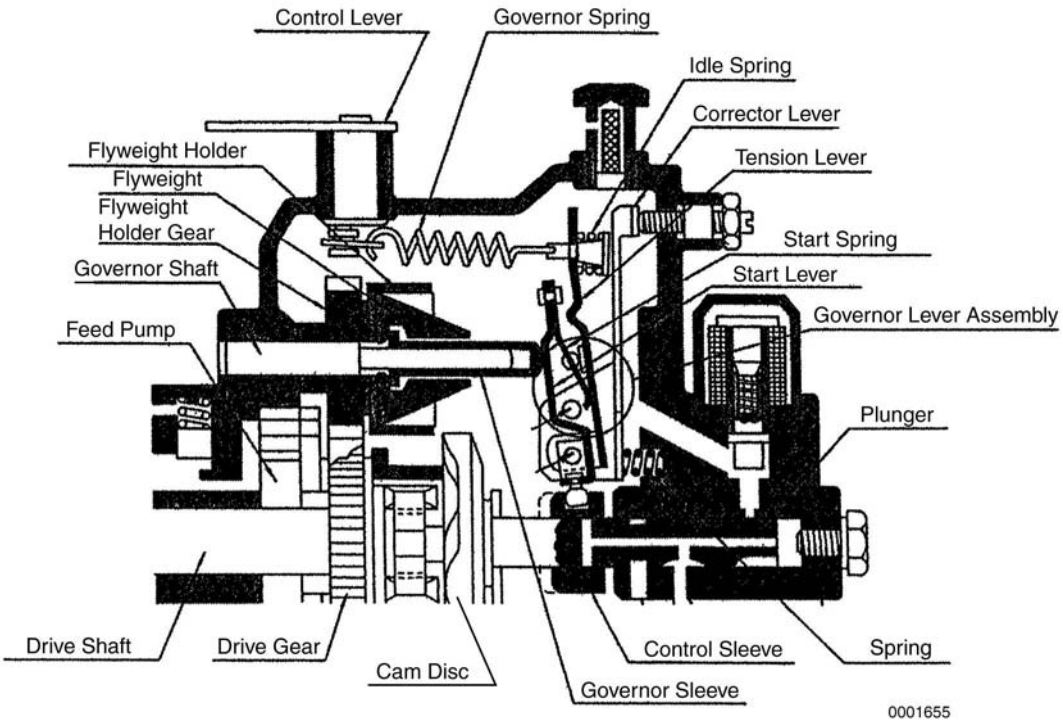


Figure 7-22

Figure7-22 shows the composition of the all-speed governor.

Revolution of the shaft is transferred to the flyweight holder acceleration gear via the drive gear to turn the flyweight holder.

The flyweight holder is supported by the governor shaft. There are four flyweights in the holder which are installed in such a way that they open outwardly by means of centrifugal force.

The flyweight movement presses the governor sleeve and presses the governor lever assembly to the right. The governor lever assembly mainly consists of the corrector leer, tension lever and start lever. Corrector lever fulcrum M, is fixed by the pivot bolt of the pump housing. Furthermore, the corrector lever cannot move since it is pressed both by the spring at the bottom and the full load adjusting screw at the top. The tension and start levers move around shaft M_2 as the fulcrum fixed on the corrector lever.

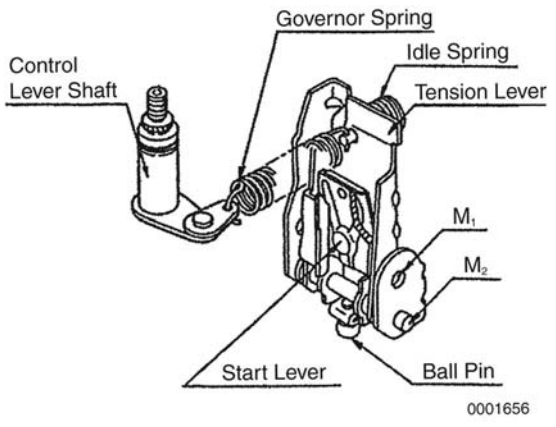


Figure 7-23

The start spring presses the start lever into the governor sleeve at engine start. The start lever turns counterclockwise around fulcrum M_2 to move the control sleeve to the start offset position.

The start and tension levers contact each other and move together during engine operation. Above the tension lever is the governor spring which is connected to the control lever. Movement of the control lever is capable of changing the set force of the governor spring. On the upper back of the tension lever is the idle spring.

The governor is controlled at all speeds by means of the start, governor and idle springs.

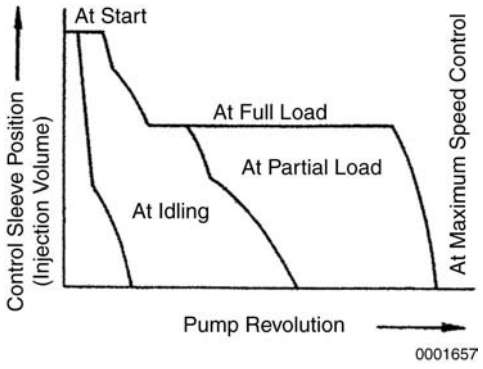


Figure 7-24

Figure7-24 shows the typical injection volume control characteristics of the all-speed governor.

At Start of Engine

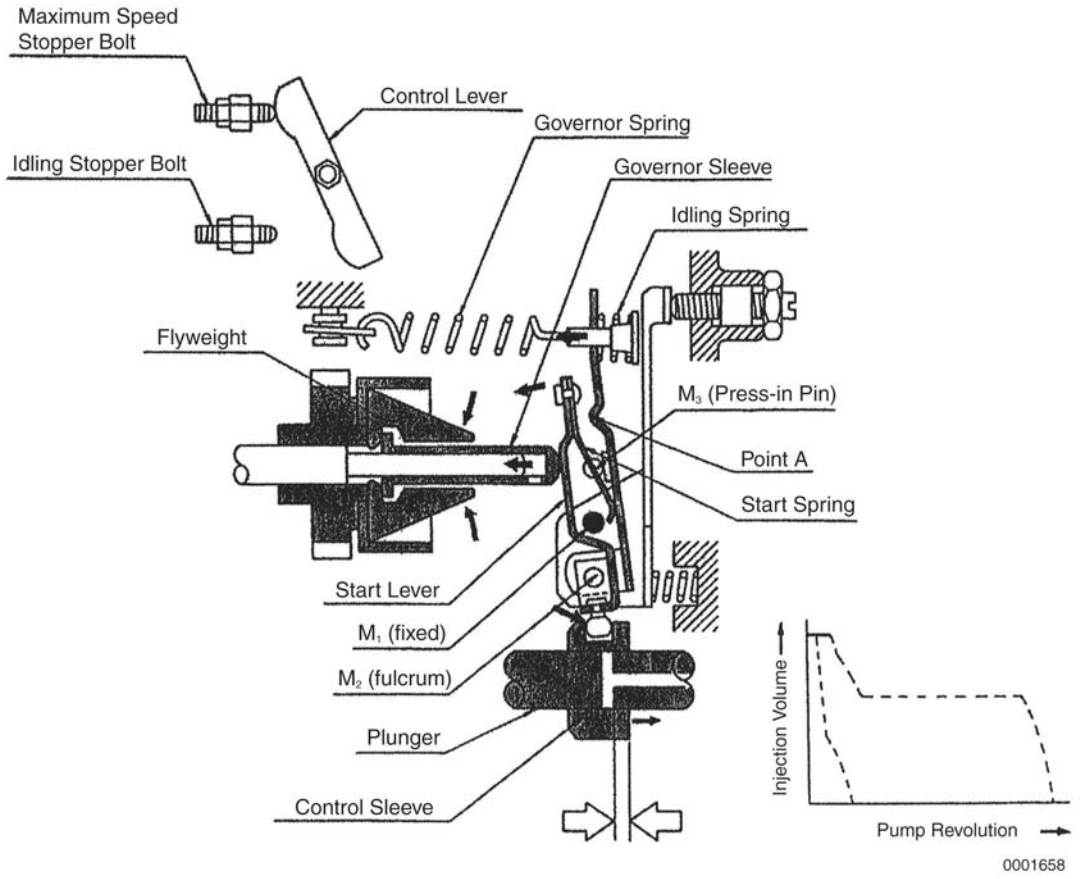


Figure 7-25

It is necessary to increase the injection volume in order to improve the starting characteristics at engine start.

When the accelerator pedal is pressed while the engine is stopped, the tension lever is pulled until it comes into contact with press-in pin M_3 by governor spring force.

At the same time, the start lever is released from the tension lever by the start spring force to press the governor sleeve to the left. THe flyweight then closes completely and the start lever moves the control sleeve to the start increasing position (to the right) with M_2 being the fulcrum.

Thus, the engine can be started easily by lightly pressing down on the accelerator pedal.

During Idling

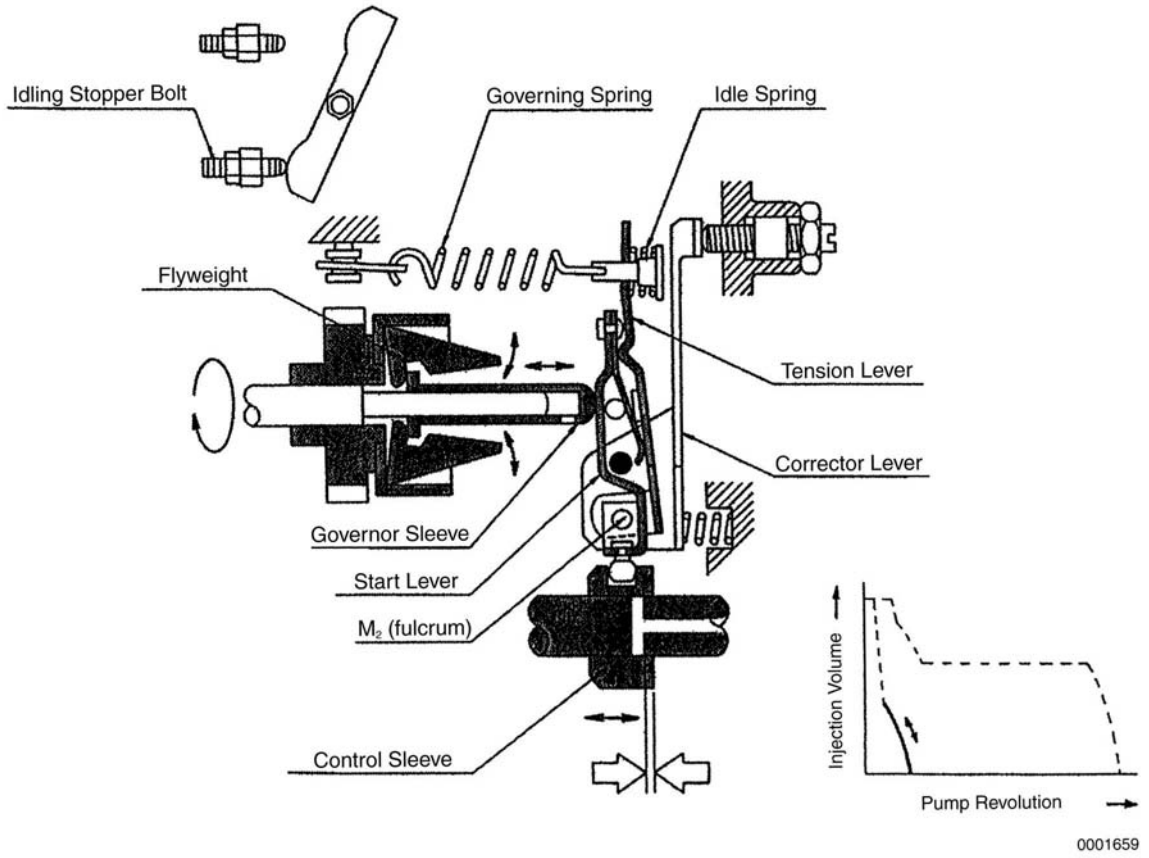


Figure 7-26

When the engine starts and the accelerator pedal is released, the control lever returns to the idle position and the tension of the governor spring becomes zero. Therefore, the flyweight opens outwardly even at low revolutions to move the governor sleeve to the right.

This makes the start lever turn clockwise with M_2 being the fulcrum to move the control sleeve in the direction to reduce the fuel volume. The governor sleeve stops at a point where the flyweight centrifugal and idle spring force are balanced to ensure stable idling.

At Full-Load Maximum Speed Control

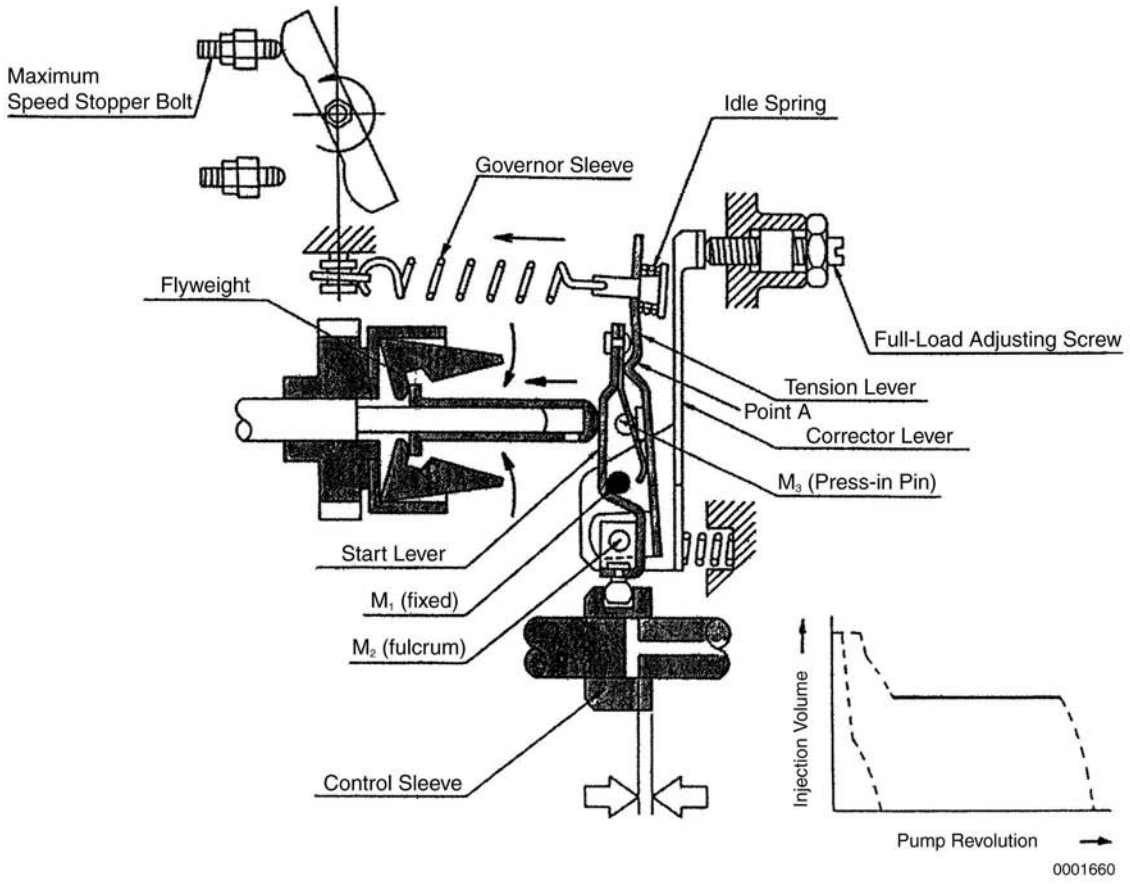


Figure 7-27

When the accelerator pedal is pressed down all the way and the control lever comes into contact with the maximum speed stopper bolt, the tension of the governor spring becomes maximum.

At this time, the tension lever is fixed at the position where is contacts pin M_3 being pressed into the pump housing. The idle spring is completely compressed to connect the start lever and the tension lever at point A, thereby holding the control sleeve at the full-load position. At this time, the flyweight is pressed by the governor sleeve and is in the completely closed state.

At No-Load Maximum Speed Control

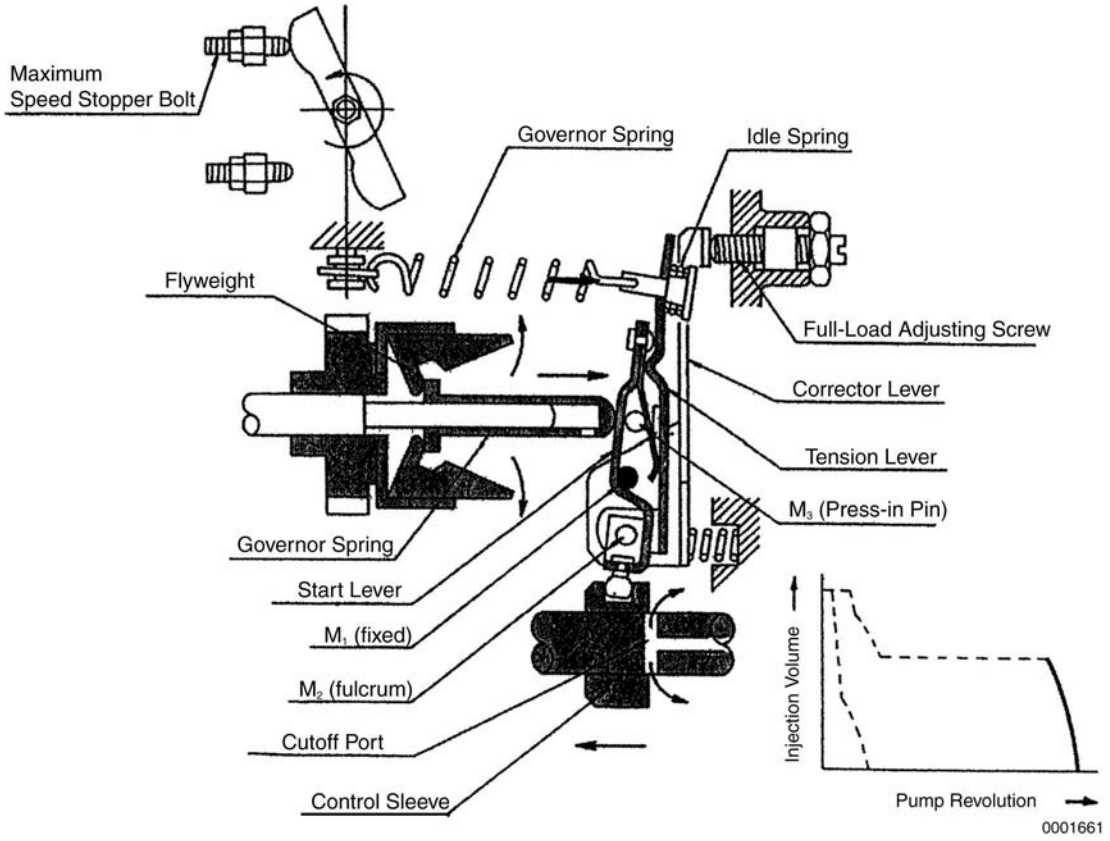


Figure 7-28

When the engine revolutions increase and the flyweight centrifugal force exceeds the governor spring set force, the governor sleeve moves to make the governor lever assembly turn clockwise with fulcrum M_2. As a result, the control sleeve moves in the direction of no-injection (to the left) for controlling speed so as not to exceed the full-load maximum speed.

When the accelerator pedal is not pressed down fully, the set force of the governor spring changes accordingly in order to achieve governor control based on the governor spring set force during partial load operation.

Full-Load Position Adjustment Mechanism

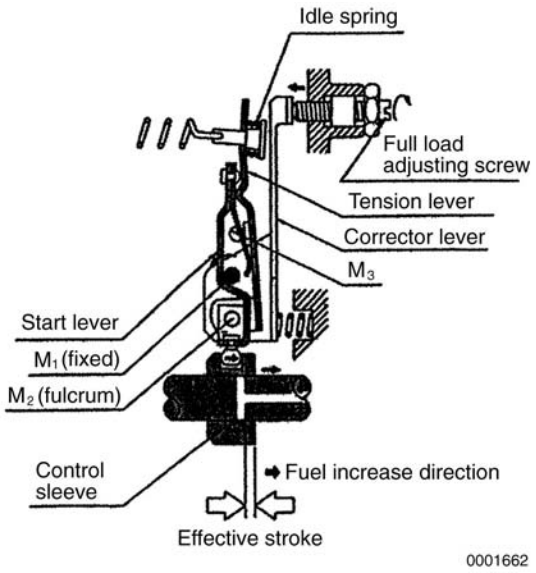


Figure 7-29

The full-load position is determined by the amount the full-load adjusting screw is driven. When the screw is driven, the corrector lever turns counterclockwise with M_1 being the fulcrum to move the control sleeve to the fuel increase direction.

When the screw is loosened, the control sleeve moves to the fuel decrease direction.

Structure And Operation Of Timer

The ignition period which occurs in the combustion process of a diesel engine tends to increase as the speed becomes higher.

Consequently, the timer is installed under the injection pump in order to correct the ignition delay period by shortening the injection timing of the injection pump.

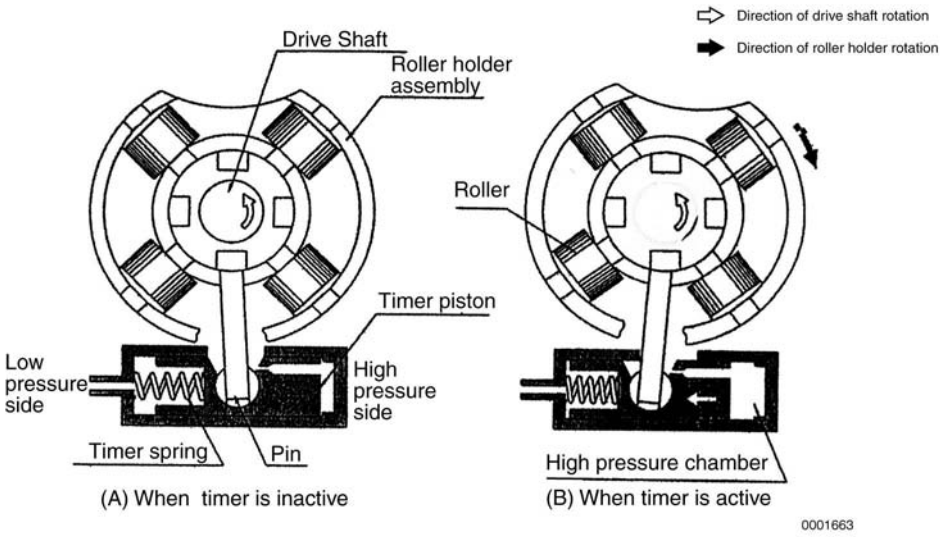


Figure 7-30

Standard Type Automatic Timer

As shown in **Figure7-30**, the inside of the timer housing is separated into low and high pressure sides, the latter directly receiving the pump chamber pressure. A timer spring having a set force is installed in the low pressure side. The timer piston slides horizontally based on the balance between the spring force and changes in the pump chamber pressure. The movement of the timer piston turns the roller holder assembly via the pin.

When pump revolutions increase and the pump chamber pressure exceeds the set force of the timer spring, the timer piston moves in the direction to compress the spring ([B] in **Figure7-30**). This turns the roller holder assembly in the reverse direction of pump revolution via the pin. This causes the crest of the cam disc to quickly approach the roller position of the roller holder, to advance the injection timing. On the contrary, when pump revolutions decrease and the timer spring force exceeds the pump chamber pressure, the timer piston moves in the direction to delay the timing.

Magnetic Valve (Stop Solenoid)

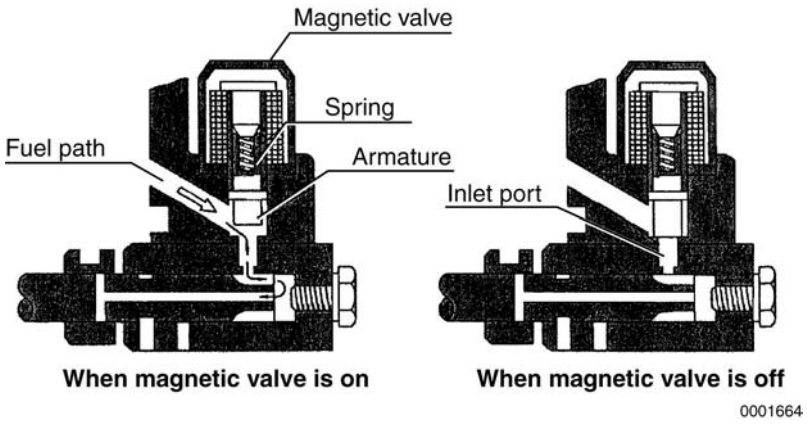


Figure 7-31

The magnetic valve (stop solenoid) turns on or off as the ignition switch of the vehicle is operated to open or close the fuel path connected to the inlet port of the plunger barrel.

When the ignition switch is turned on, power is supplied to the magnetic valve to lift the armature, thus opening the fuel path.

On the contrary, when the ignition switch is turned off, the armature is powered by the force of the spring installed in the armature to close the fuel path. As a result, no fuel is fed to the plunger, stopping the engine immediately.

Removal Of Fuel Injection Pump

1. Remove fuel supply line from the fuel injection pump.

2. Remove fuel injector return line.

3. Remove fuel tank return line.

4. Disconnect the electrical connection to the magnetic valve (stop solenoid) **(Figure7-32, (1)).**

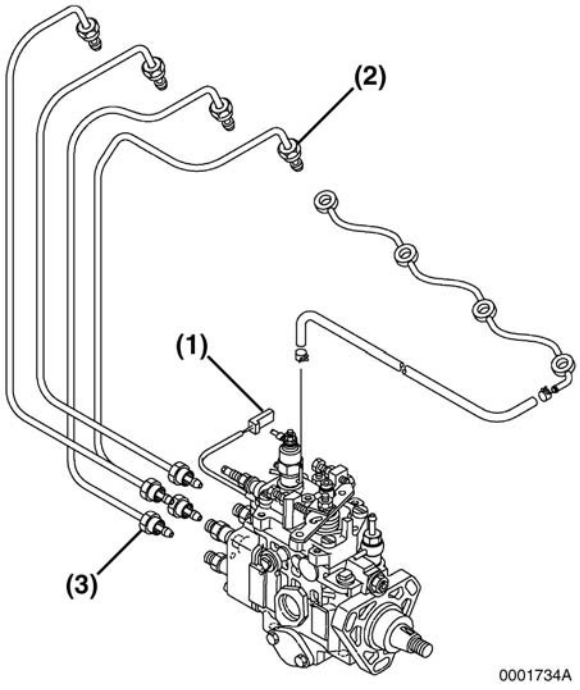


Figure 7-32

5. Disconnect the throttle linkage.

6. Remove the high pressure fuel lines.

- First loosen the high pressure fuel line nuts **(Figure7-32, (2))** at the fuel injectors.

CAUTION

When loosening or tightening the lines at the fuel injectors, you must hold the fuel injector with a second wrench to prevent the injector from turning and damaging the fuel return line fitting.

- Then loosen the high pressure fuel line nuts **(Figure7-32, (3))** on the fuel injection pump.
- Finish loosening all the high pressure fuel line nuts and remove the fuel lines as an assembly. Be careful not to bend any of the fuel lines.

CAUTION

Remove the high-pressure fuel injection lines as an assembly whenever possible.

Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

NOTE: It is necessary to remove the bolt **(Figure7-33, (1))** holding the dipstick tube clamp. Rotate the dipstick tube to one side to allow you to remove the high pressure fuel line assembly.

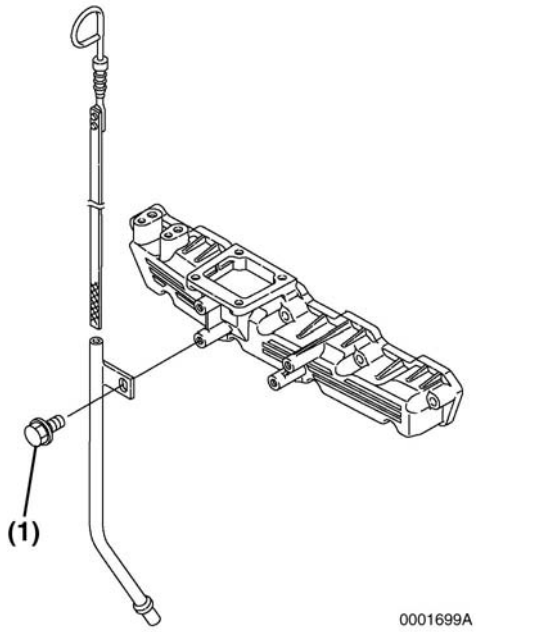


Figure 7-33

7. Remove the two bolts **(Figure7-34, (1))** from the L-shaped brackets that holds the injection pump at the bottom / rear.

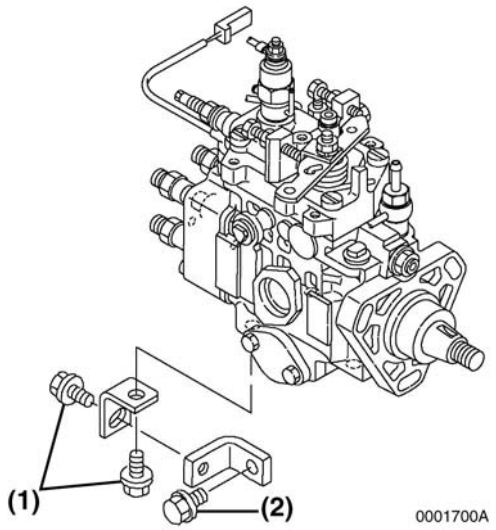


Figure 7-34

- Loosen the bolt **(Figure7-34, (2))** that fastens the remaining bracket to the cylinder block and pivot down and away from the injection pump.

8. Loosen the alternator adjusting bolt and pivot the alternator toward the engine.

⚠ CAUTION

PINCH HAZARD!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

9. Remove the cooling fan **(Figure7-35, (1))**, spacer (if equipped) **(Figure7-35, (2))** and V-belt **(Figure7-35, (3))**.

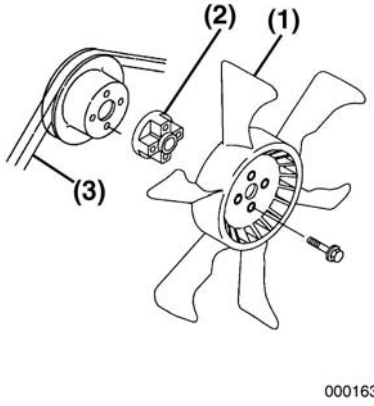


Figure 7-35

10. Remove the seven bolts from the fuel injection pump cover **(Figure7-36, (1))** on the front gear case. Remove the cover.

NOTE: The cover is secured with an adhesive sealant. Use a gasket scraper to separate the cover from the gear case.

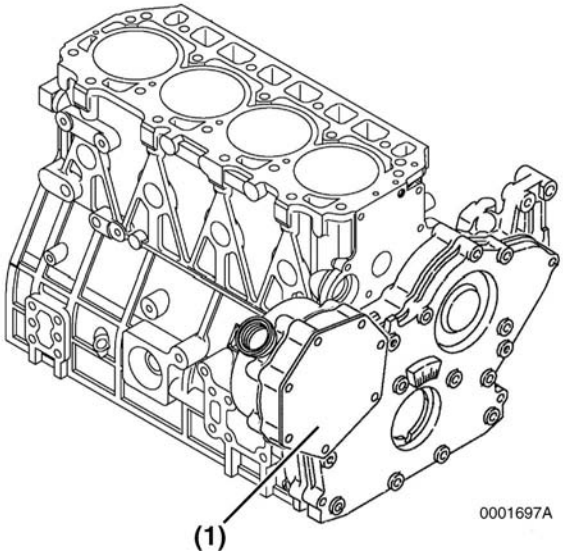


Figure 7-36

11. To aid in reassembly, mark one tooth on the idle gear and two teeth on the pump drive gear with a dot of white paint. See **(Figure 7-37).**

CAUTION

Do not rotate the engine with the injection pump removed.

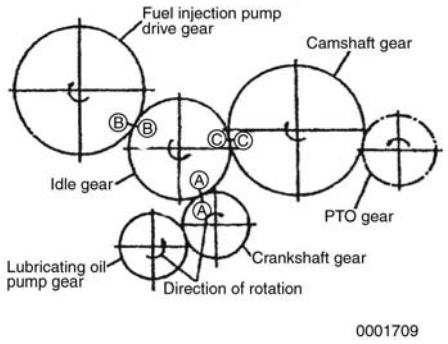


Figure 7-37

Also make matching marks **(Figure7-38, (1))** on the rear of the gear case housing and on the fuel injection pump mounting flange before loosening the injection pump mounting nuts.

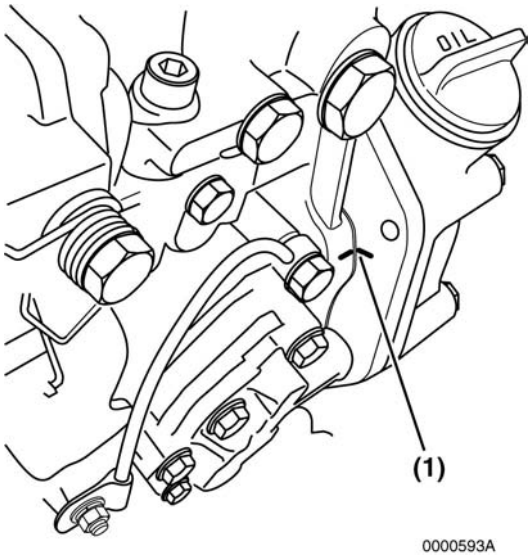


Figure 7-38

12. While holding the engine from turning with a wrench on the crankshaft pulley bolt, remove the pump drive gear retaining nut **(Figure7-39, (1))** and lock washer **(Figure7-39, (2))**.

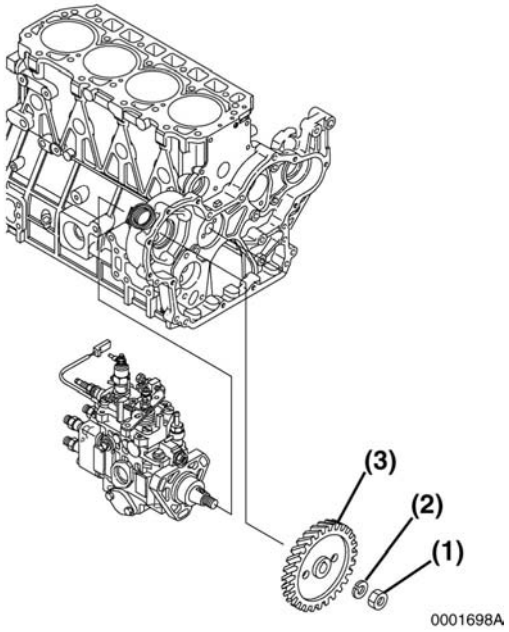


Figure 7-39

13. Using a two-bolt gear puller, remove the injection pump drive gear **(Figure7-39, (3))** from the injection pump shaft.

NOTE: The injection pump shaft is tapered with a woodruff key. Once you have applied some pressure with the puller. A slight hammer “tap” on the center puller bolt will help “pop” the gear from the shaft.

14. Remove the three nuts securing the fuel injection pump to the rear of the gear case.

15. Remove the fuel injection pump.

16. If the fuel injection pump requires servicing, it must be taken to an authorized ZEXEL fuel injection shop.

Installation Of The Fuel Injection Pump

1. Secure the fuel injection pump mounting flange to the rear of the gear case housing with three nuts. Be sure to match the marks **(Figure7-40, (1))** on the rear of the gear case housing and on the fuel injection pump mounting flange.

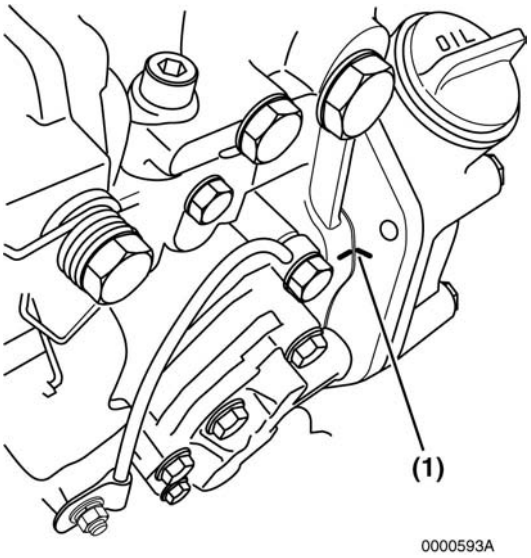


Figure 7-40

2. Install the injection pump drive gear **(Figure7-42, (3))** on the injection pump shaft lining up the two marks you made on the pump drive gear with the mark you made on the idle gear. See **(Figure7-37).**

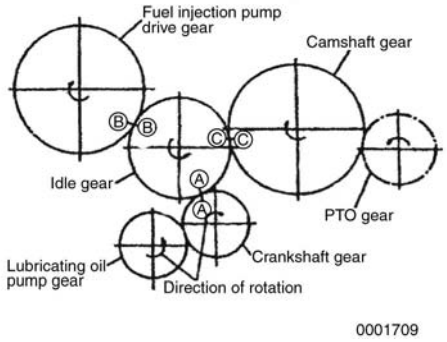


Figure 7-41

3. Install the drive gear retaining nut **(Figure7-42, (1))** and washer **(Figure7-42, (2))**. While holding the engine with a wrench on the crankshaft pulley bolt, torque the retaining nut to 43.5 - 51 ft lbs (59-69 N·m, 5 - 5.4 kgf·m).

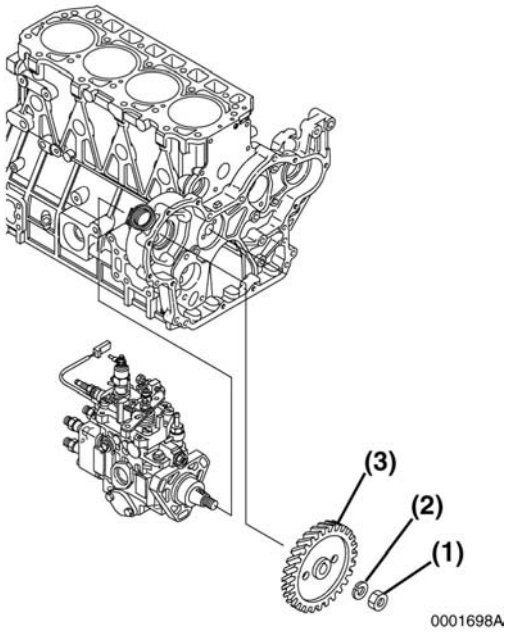


Figure 7-42

4. Thoroughly clean all old sealant from the fuel injection pump cover **(Figure7-43, (1))** and gear case housing. Apply ThreeBond, Yanmar Part No. 977770-01212, or equivalent sealant to the fuel injection pump cover. Install the fuel injection pump cover on the front gear case with seven bolts. Tighten the bolts to the specified torque.

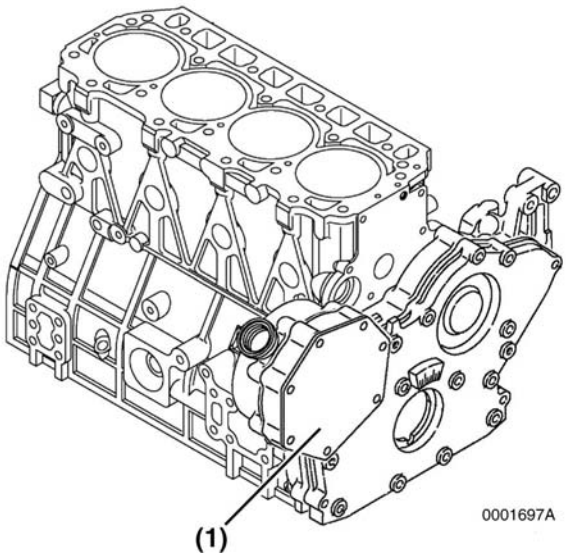


Figure 7-43

5. Reinstall the cooling fan **(Figure7-44, (1))**, spacer (if equipped) **(Figure7-44, (2))** and V-belt **(Figure7-44, (3))**.

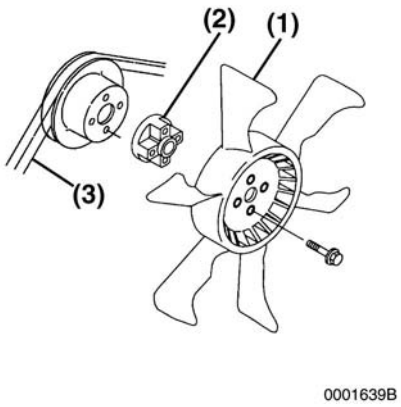


Figure 7-44

6. Pivot the alternator away from the engine and adjust the V-belt tension. See Check and Adjust Cooling Fan V-belt on page 47.

7. Tighten the alternator adjusting bolt. See Check and Adjust Cooling Fan V-belt on page 47.

8. Pivot the bracket that fastens the fuel injection pump to the cylinder back up and toward the fuel injection pump. Retighten the bolt **(Figure 7-45, (2))** that fastens it to the cylinder block.

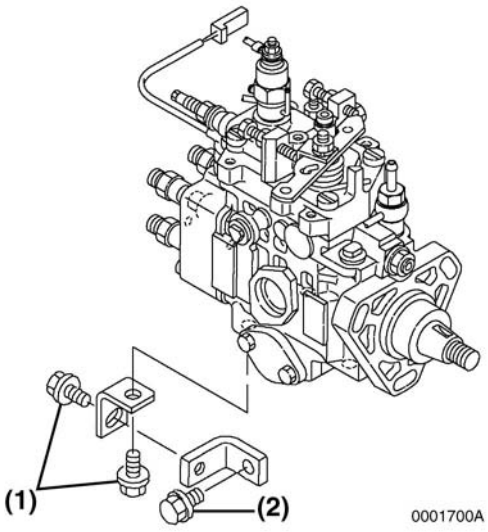


Figure 7-45

9. Reinstall the two bolts **(Figure7-45, (1))** to the L-shaped bracket that holds the injection pump at the bottom / rear. Tighten the two bolts and the bolt that secures the bracket to the cylinder block to specified torque.

10. Reinstall the high pressure fuel lines.

- Replace the high pressure fuel lines as an assembly. Be careful not to bend any of the high pressure fuel lines.
- Start all the high pressure fuel line nuts by hand, leaving those nuts on the fuel injection pump and fuel injectors untightened.
- Tighten the high pressure fuel line nuts **(Figure7-46, (2))** on the fuel injection pump.
- Tighten the high pressure fuel line nuts **(Figure7-46, (1))** on the fuel injectors.

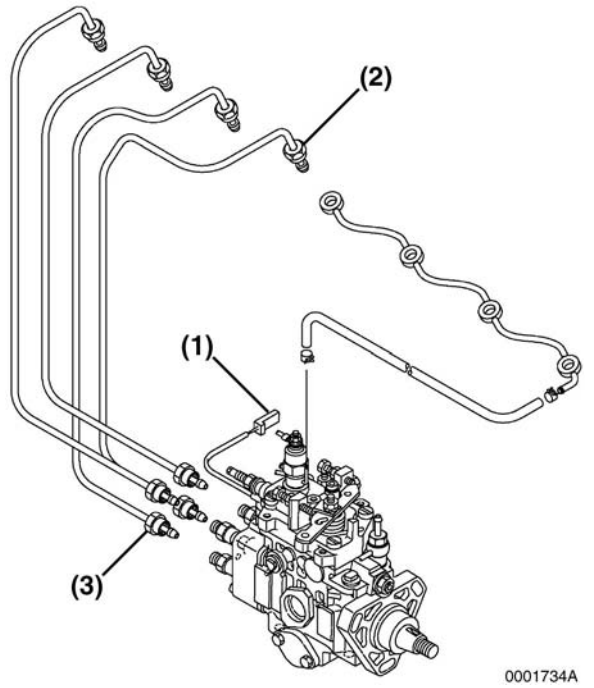


Figure 7-46

11. Reconnect the throttle linkage.

12. Reconnect the electrical connection to the magnetic valve (stop solenoid) **(Figure7-46, (1)).**

13. Reinstall fuel tank return line.

14. Reinstall fuel injector return line.

15. Reinstall fuel supply line to the fuel injection pump.

16. Prime the fuel system and check for leaks.

Checking / Adjustment Of Fuel Injection Timing

1. Using a wrench on the front crankshaft pulley bolt, rotate the engine clockwise until the timing mark on the crankshaft pulley is aligned with the “O” or TDC (Top Dead Center) mark on the timing grid of the gear case cover.

2. Remove the center bolt **(Figure7-47, (1))** and sealing washer from the rear of the fuel injection pump.

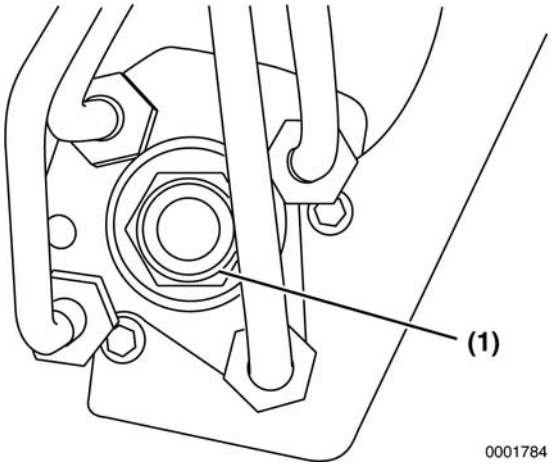


Figure 7-47

3. Locate Yanmar timing tool (P/N 119770-02020) **(Figure7-48, (1))**. Install a dial indicator into the timing tool.

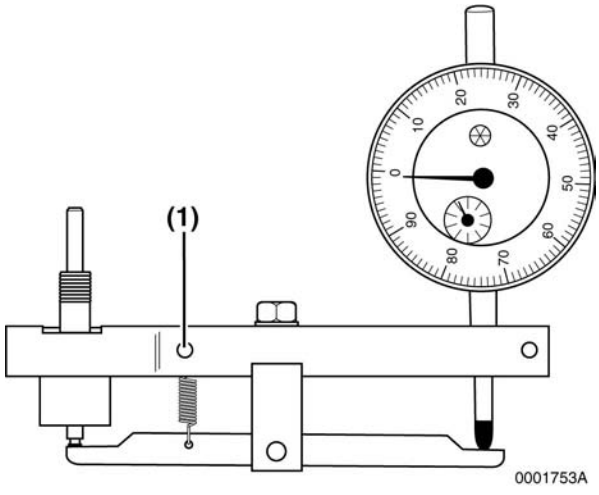


Figure 7-48

4. Install Yanmar timing tool **(Figure7-49, (1))**, into the port where the bolt was removed. This will provide a reading of the injection pump plunger lift.

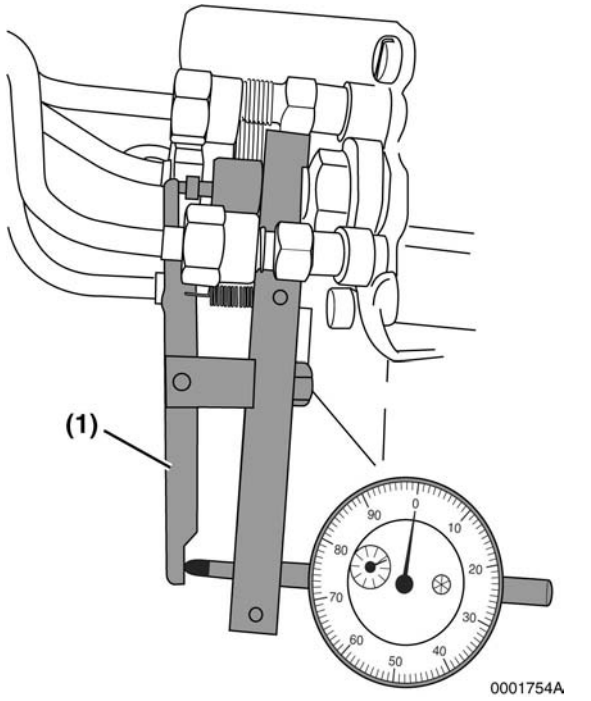


Figure 7-49

5. Rotate the engine about 25° in the counterclockwise direction. The dial indicator should move for approximately the first 10° of engine rotation and then stop. When you reach approximately the 25° position, rotate the engine slightly back and forth to make sure the needle of the dial indicator does not move.

6. Set the dial indicator to “0”.

7. Rotate the engine in the clockwise rotation until the timing mark on the crankshaft pulley is aligned with the mark at 4, 6 and 8.5° ATDC (After Top Dead Center) on the timing grid on the gear case cover.

8. 5deg ATDC.8.If the injection timing is correct, the dial indicator should read 0.038 - 0.041 in (0.97 - 1.03 mm).

9. If the injection timing is not correct, loosen the three fuel Injection pump mounting nuts and the bolts retaining the bottom / rear L-shaped injection pump mounting brackets. Rotate the injection pump to bring the dial indicator reading into the correct range.

10. Then retighten the pump mounting nuts and the mounting bracket bolts.

NOTE: Rotating the injection pump away from the engine advances the injection timing. Rotating the injection pump toward the engine retards the injection timing.

11. Remove the timing tool and dial indicator. Replace and tighten the center bolt and sealing washer into the injection pump port.

Servicing The Fuel Injectors

Removal of the Fuel Injectors

1. Remove the high pressure fuel lines.

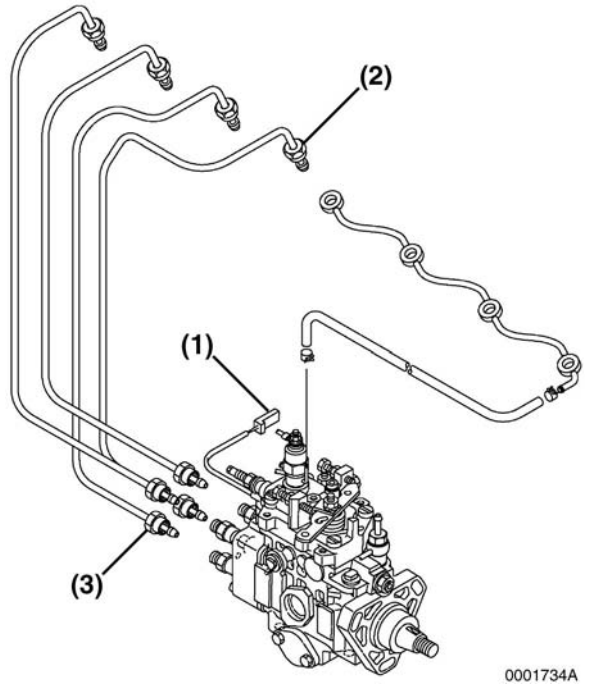


Figure 7-50

- First just loosen the high pressure fuel line nuts **(Figure7-50, (2))** at the fuel injectors.

CAUTION

When loosening or tightening the lines at the fuel injectors, you must hold the fuel injector with a second wrench to prevent the injector from turning and damaging the fuel return line fitting.

- Then loosen the high pressure fuel line nuts **(Figure7-50, (3))** on the fuel injection pump.
- Finish loosening all the high pressure fuel line nuts and remove the fuel lines as an assembly. Be careful not to bend any of the fuel lines.

CAUTION

Remove the high-pressure fuel injection lines as an assembly whenever possible.

Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

NOTE: It is necessary to remove the bolt **(Figure7-51, (1))** holding the dipstick tube clamp. Rotate the dipstick tube to one side to allow you to remove the high pressure fuel line assembly.

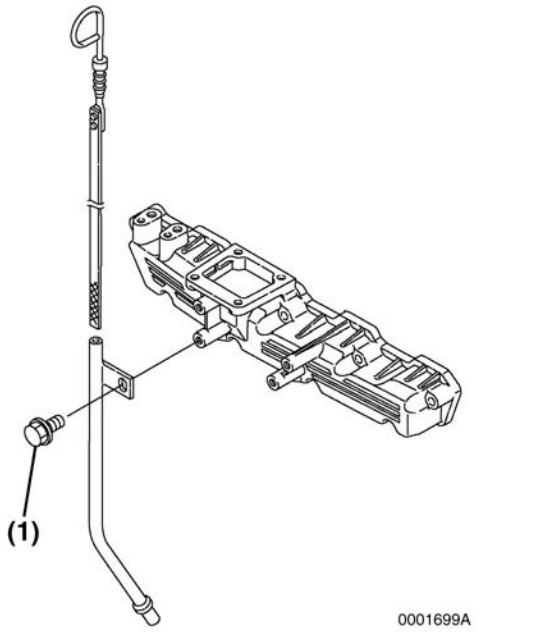


Figure 7-51

2. Unscrew the fuel injectors from the cylinder head. Also remove the two copper washers and the nozzle protectors that will remain in the cylinder head.

Inspection and Testing of the Fuel Injectors

Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean and repair as necessary.

Test Procedure Using a Nozzle Tester

1. Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean, repair or replace as necessary.

2. Test the fuel injector using an injection nozzle tester. Use clean, filtered fuel or F.I.E. calibration fluid for the test.

3. Using the correct adaptor, connect the fuel injector to the high-pressure pipe of the nozzle tester. Aim the fuel injector into a suitable container to catch the fuel spray.

⚠ WARNING

- **Never inject fuel towards you. Since the fuel in injected at high presure from the nozzle, it may penetrate the skin, resulting in injury.**
- **Never inject fuel towards a fire source. Atomized fuel is highly flammable and may cause fire or skin burning.**

4. Pump the operating lever of the tester slowly, observing the pressure reading at the point where the fuel injector begins spraying fuel. The fuel injectors for these engines should begin spraying fuel at 1711 - 1914 PSI (11.8 - 13.2 MPa). The opening pressure may be adjusted by adding or subtracting internal fuel injector shims.

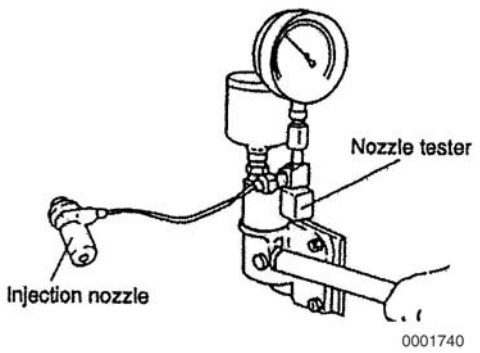


Figure 7-52

5. Adding or removing a 0.1 mm shim (shims are available in 0.4 mm increments) changes the pressure by 174 - 319 PSI (1.2 - 2.2 MPa).

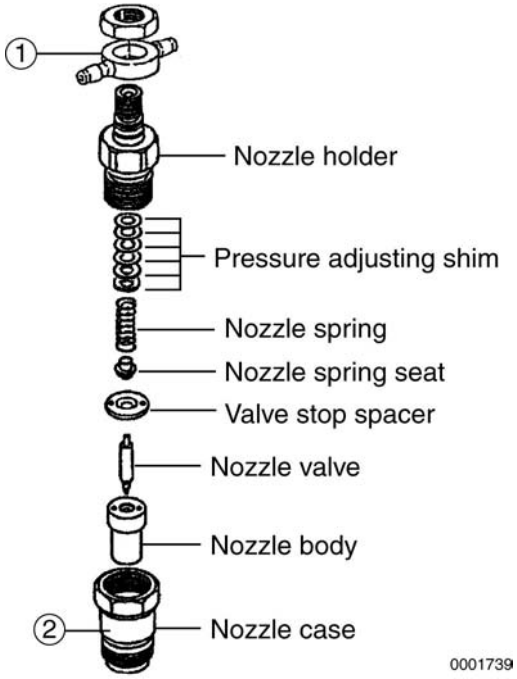


Figure 7-53

6. Pump the operating lever more rapidly to repeatedly “pop” the injector and observe the spray pattern. See Judgement Criteria on Atomization Conditionon page7-37 for examples of “good” and “bad” spray patterns.

7. Finally. Pump the operating lever slowly to hold the pressure steady at a point just below the “pop off” pressure point. Observe the injector to see that it is sealing properly and is not “dripping”.

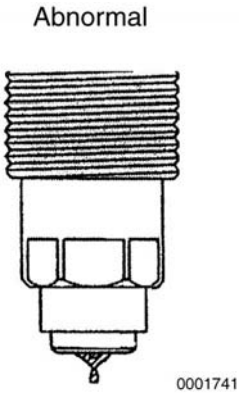
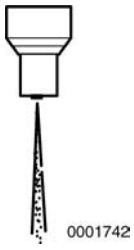
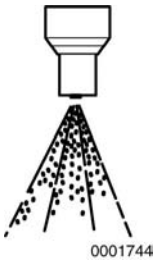
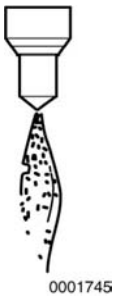
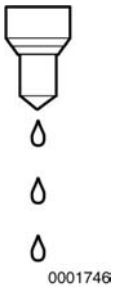


Figure 7-54

8. If the fuel injector fails any of these tests, it should be repaired or replaced as necessary.

Judgement Criteria on Atomization Condition

	A	B	C	D	E
Injection Pattern					
Pressure Gauge Reading	Pointer fluctuate around the valve opening pressure.	Same as A.	Pointer stays at a position near the valve opening pressure.	Although the pointer reaches the valve opening pressure, the pressure drop is large.	Pressure does not increase even when the tester lever is
Atomization Pattern	Roughly uniform.	Atomization is excessively one sided.	Although atomized, the needle does not pulsate (burner like shape).	Bar shape with excessive after drops.	Drops (bar shape).
Possible Cause	(Normal)	**1.** Normally caused by carbon contamination of the nozzle tip. **2.** Sometimes caused by flaws in or damage to the needle tip.	**1.** Caused by excessive carbon contamination of the nozzle tip. **2.** Sometimes caused by contamination .	**1.** Damage to the seat. **2.** Contamination of seat by fine foreign particles. **3.** Excessively worn seat.	**1.** Sticking of needle. **2.** Excessively damaged or worn seat. **3.** Contamination of seat by foreign matter. **4.** Damaged or broken internal parts od nozzle holder.

Cleaning of Nozzle

1. Clean the exterior of the nozzle, taking care not to damage the needle.

2. Pull out the needle and clean carefully so as not to damage it. Avoid use of hard, metallic tools.

3. Check for dents, damage, rusting and wear. Pay special attention to the stem and seat of the needle.

4. When setting the needle on the nozzle body after thorough cleaning, check that it falls by its own weight.

Installation of Fuel Injectors

1. Install a new copper gasket at the bottom of the injector well.

2. Install the nozzle protector in the injector well.

3. Install the second copper gasket on top of the nozzle protector.

4. Install the fuel injectors. Torque to 29.4ft·lb (39.2N·m).

5. Install the fuel return line fitting using new copper gaskets.

6. Tighten the fuel return line retaining nuts to 32.5ft·lb (44.1N·m).

CAUTION

When loosening or tightening the lines at the fuel injectors, you must hold the fuel injector with a second wrench to prevent the injector from turning and damaging the fuel return line fitting.

7. Reinstall the high pressure fuel lines and fuel return line.

- Replace the high pressure fuel lines as an assembly. Be careful not to bend any of the high pressure fuel lines.
- Start all the high pressure fuel line nuts by hand, leaving those nuts on the fuel injection pump and fuel injectors untightened.
- Tighten the high pressure fuel line nuts **(Figure7-55, (2))** on the fuel injection pump.
- Tighten the high pressure fuel line nuts **(Figure7-55, (1))** on the fuel injectors.

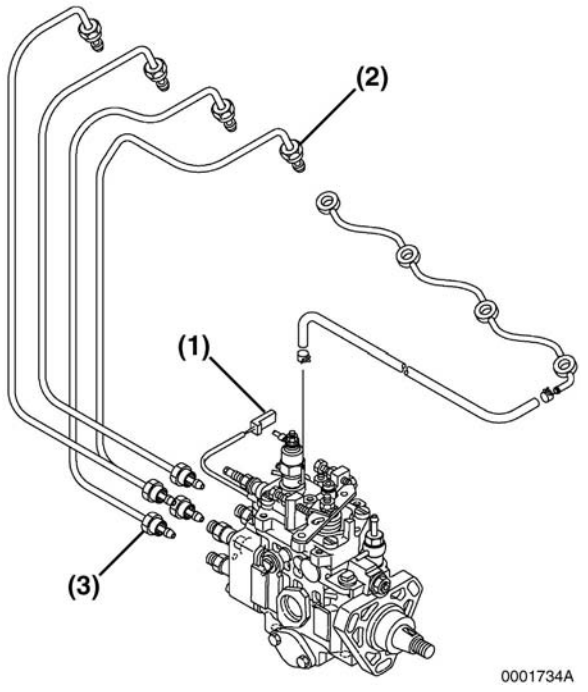


Figure 7-55

8. Prime the fuel system and check for leaks.

Section 5. COOLING SYSTEM

Before You Begin Servicing

⚠ DANGER

SCALD HAZARD!

NEVER remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

ALWAYS check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.

⚠ WARNING

ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it.

NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.

Failure to comply could result in death or serious injury.

⚠ WARNING

BURN HAZARD!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.

⚠ WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

⚠ WARNING

BURN HAZARD!

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

ALWAYS wear eye protection.

Failure to comply could result in death or serious injury.

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

⚠ CAUTION

PINCH HAZARD!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and/or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

CAUTION

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.

CAUTION

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.

Introduction

This section of the Service Manual describes the procedures necessary to service the 4TNV84 engine coolant pump. This engine coolant pump is representative of the coolant pumps used on other TNV model engines. For specific part detail, see the parts catalog for the engine you are working on.

Cooling System Diagram

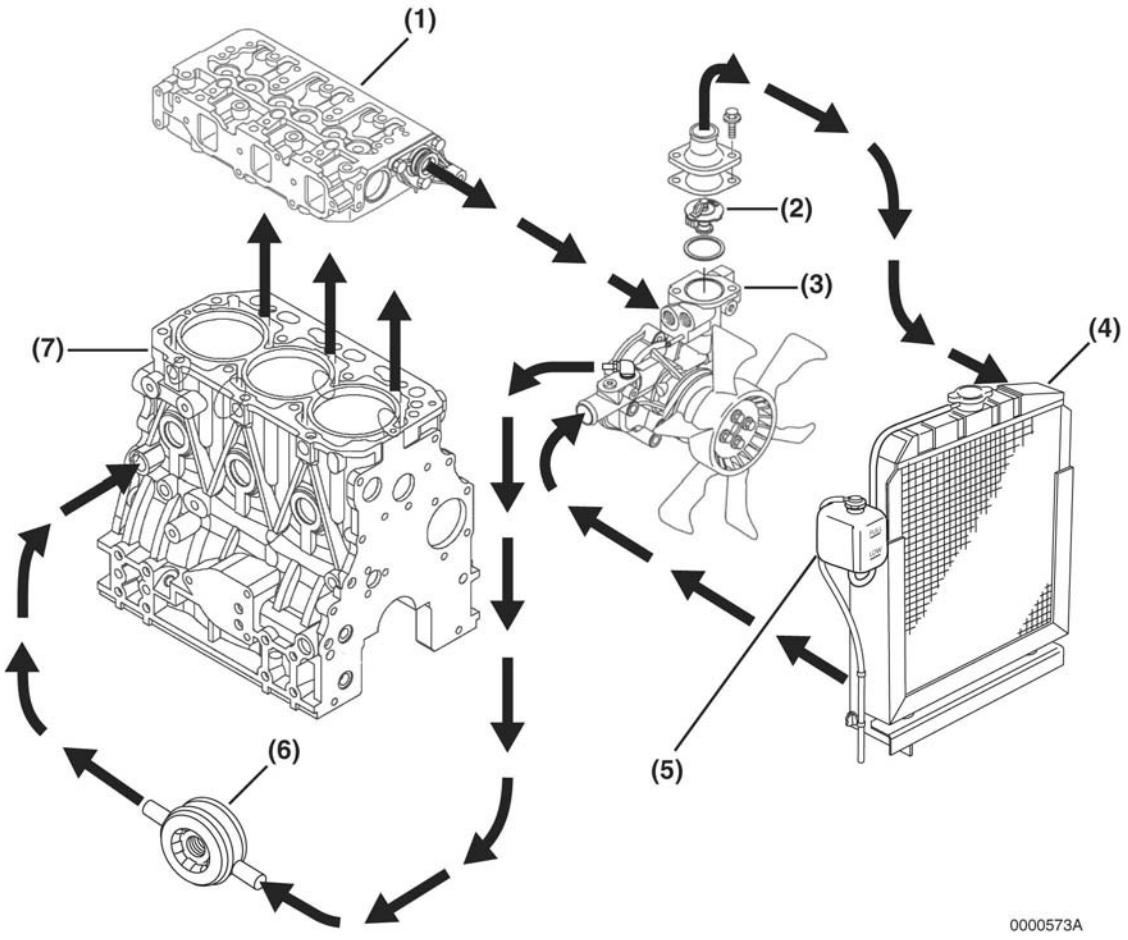


Figure 8-1

(1) Cylinder Head. (2) Thermostat. (3) Engine Coolant Pump. (4) Radiator. (5) Coolant Recovery Tank. (6) Engine Oil Cooler*
(7) Cylinder Block

* Not standard on all models.

Engine Coolant Pump Components

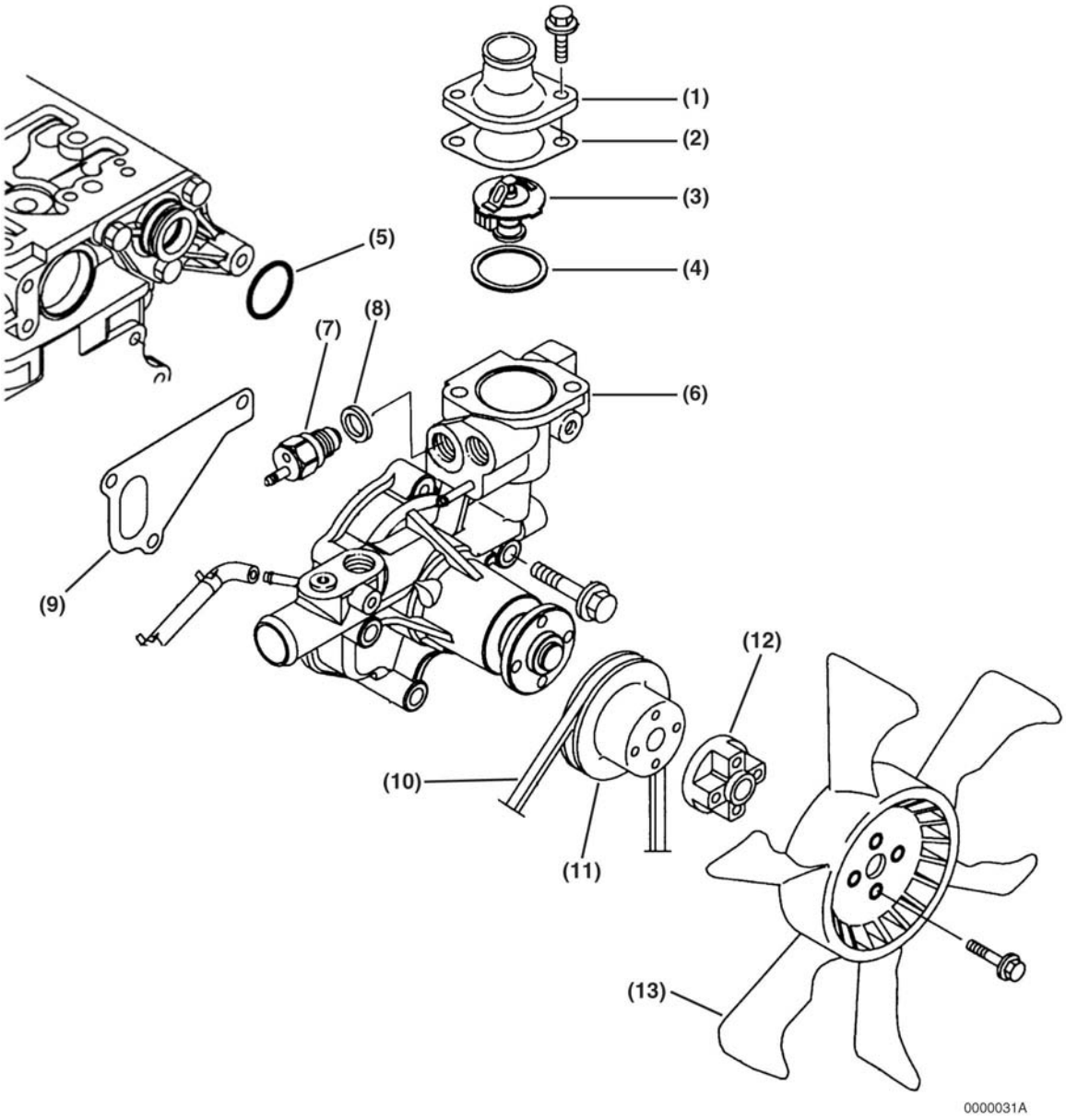


Figure 8-2

(1) Thermostat Cover. (2) Thermostat Cover Gasket. (3) Thermostat. (4)Thermostat O-Ring. (5) Special O-Ring.
(6) Engine Coolant Pump. (7) Temperature Switch. (8) Gasket. (9) Engine Coolant Pump Gasket. (10) V-Belt.
(11) Engine Coolant Pump V-Pulley. (12) Spacer. (13) Engine Coolant Fan

Engine Coolant System Check

Check the engine coolant system for leakage.

1. With the radiator properly filled, install a cooling system tester **(Figure 8-3, (1))**.

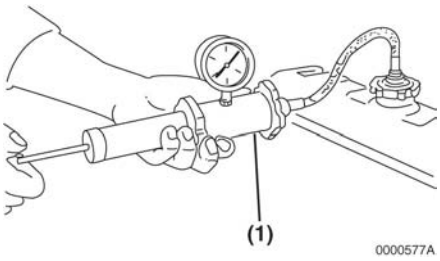


Figure 8-3

2. Apply 10.8-14.8 psi (75-105 kPa; 0.75-1.05 kgf/cm²) to the cooling system. If the pressure reading drops, the engine coolant system is leaking. Identify the source of the leak and repair it.

Engine Coolant Pump

Removal of Engine Coolant Pump

Verify the condition of the engine coolant pump before disassembling it from the engine. Check the engine coolant pump shaft bearing for abnormal noise, sticking, excessive play and water leakage. Replace the coolant pump if any of these conditions are present.

CAUTION

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.

IMPORTANT

Make sure the engine and engine coolant are not hot.

1. Before removing the engine coolant pump or thermostat, it will be necessary to drain the engine coolant. Drain the coolant into a clean container if the coolant is to be reused. Otherwise, properly dispose of the coolant.

2. Remove the radiator cap **(Figure 8-4, (1)).**

3. Remove the drain plug or open the drain cock **(Figure 8-4, (1))** at the lower portion of the radiator and drain the coolant.

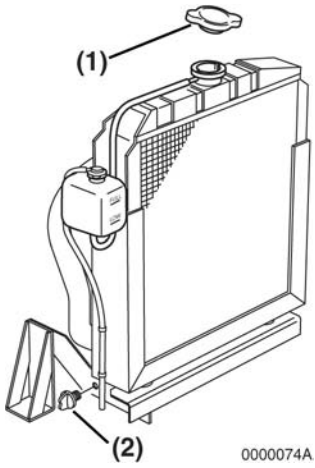


Figure 8-4

4. Drain the coolant from the engine block.

- On models equipped with an oil cooler, remove the coolant hose **(Figure 8-5, (1))** at the oil cooler.

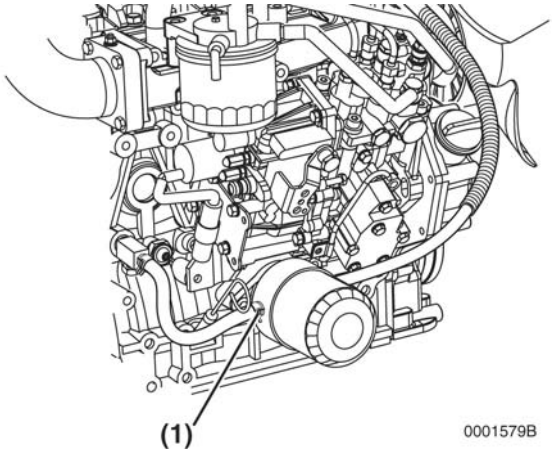


Figure 8-5

• On models not equipped with an oil cooler, remove the coolant drain plug **(Figure 8-6, (1))** from the engine block.

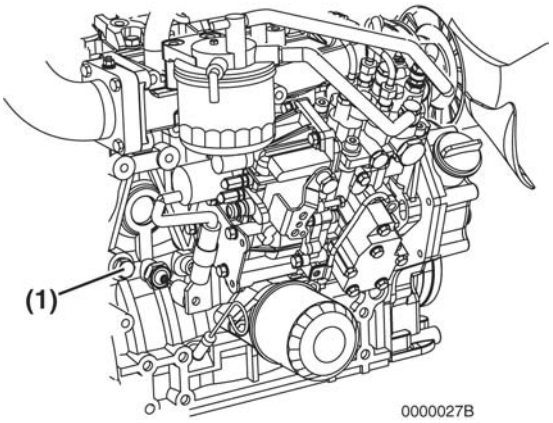


Figure 8-6

5. Loosen the alternator mounting bolts. Loosen and remove the V-belt and rotate the alternator away from the engine and out of the way.

⚠ CAUTION

PINCH HAZARD!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

6. Remove the engine coolant fan guard (if equipped), engine coolant fan **(Figure 8-7, (1))**, spacer **(Figure 8-7, (2))** and engine coolant pump V-pulley **(Figure 8-7, (3))**.

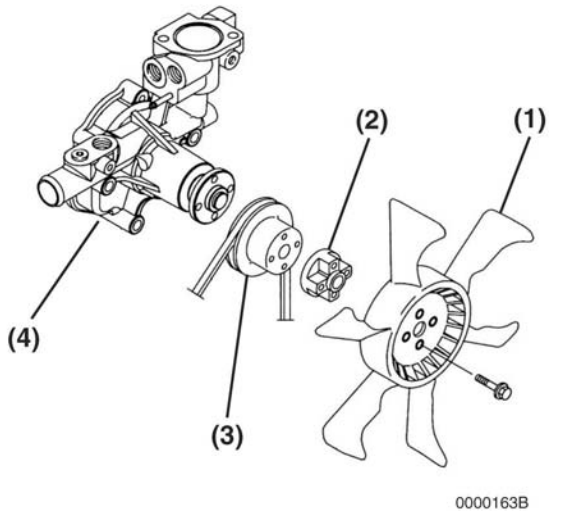


Figure 8-7

7. Disconnect the coolant hoses and the temperature switch lead wire from the engine coolant pump.

8. Remove the engine coolant pump **(Figure 8-7, (4))**. Discard the gasket.

Disassembly of Engine Coolant Pump

1. Remove the thermostat cover **(Figure 8-8, (1))**. Discard the gasket.

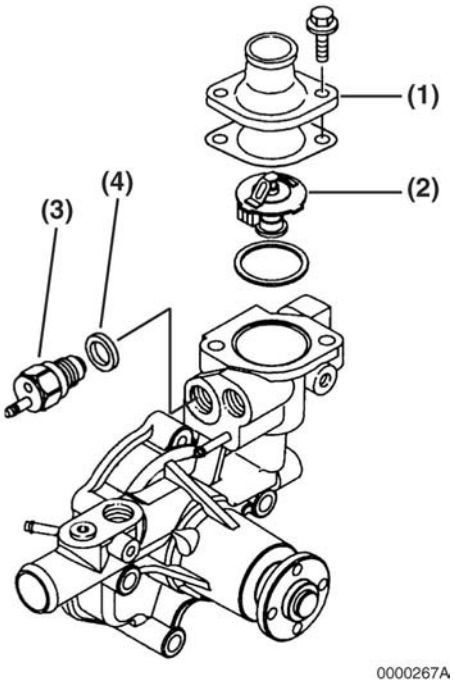


Figure 8-8

2. Remove the thermostat **(Figure 8-8, (2))**. Discard the O-ring. Remove the temperature switch **(Figure 8-8, (3))** and gasket **(Figure 8-8, (4))**. Discard the gasket.

Cleaning and Inspection

Thermostat

1. Check for proper operation of the thermostat. Place the thermostat **(Figure 8-10, (1))** and an accurate thermometer **(Figure 8 -10, (2))** in warm water.

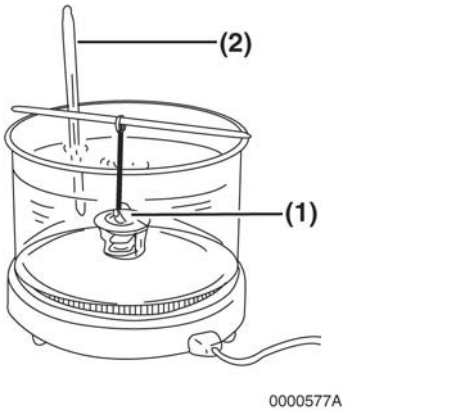


Figure 8-10

2. Slowly increase the temperature of the water using an external heat source.

3. The thermostat is operating properly if it starts to open at the temperature value stamped on the flange of the thermostat, and fully opens as the temperature of the water is increased.

Radiator Cap

1. Check for proper operation of the radiator cap. Install the radiator cap **(Figure 8-11, (1))** on a cooling system tester.

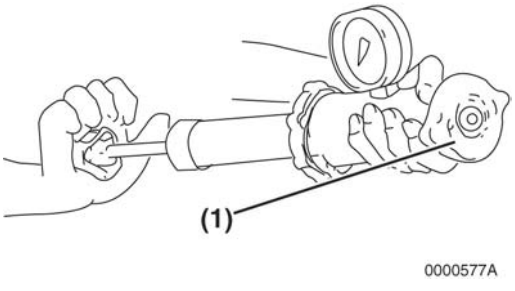


Figure 8-11

2. Apply 10.8 - 14.8 psi (75 - 105 kPa; 0.75 - 1.05 kgf/cm²) to the radiator cap. The radiator cap relief valve must open within the specified range.

Reassembly of Engine Coolant Pump

1. Reinstall the thermostat **(Figure 8-12, (1))** and a new O-ring.

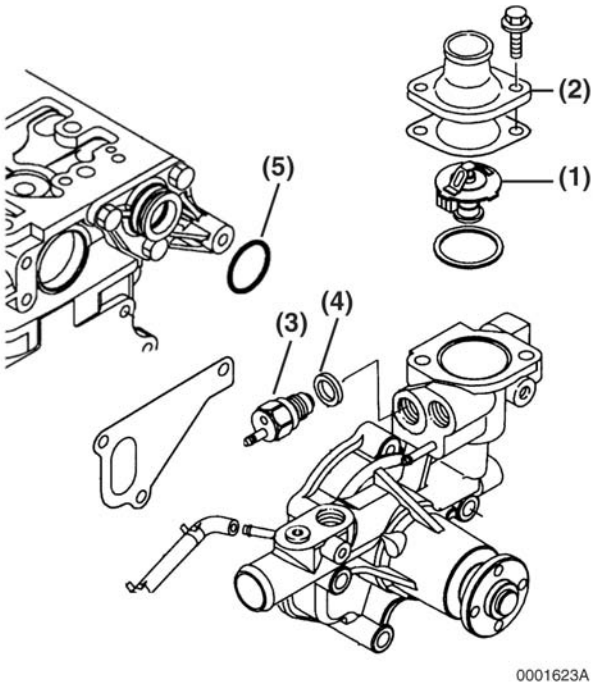


Figure8-12

2. Reinstall the thermostat cover **(Figure 8-12, (2))** and a new gasket. Tighten the thermostat cover bolts.

3. Reinstall the temperature switch **(Figure 8-12, (3))** and a new gasket **(Figure 8-12, (4))**.

Installation of Engine Coolant Pump

1. Position the engine coolant pump on the engine and install a new gasket. Install a new special O-ring **(Figure 8-12, (5))** on assembly between the engine coolant pump and the joint.

CAUTION

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.

2. Reinstall the engine coolant pump bolts. Tighten the bolts.

3. Inspect and reinstall the coolant hoses and the temperature switch lead wire.

4. Reinstall the engine coolant pump V-pulley **(Figure 8-13, (1))**, spacer **(Figure 8-13, (2))** engine coolant fan **(Figure 8-13, (3))** and engine coolant fan guard (if equipped).

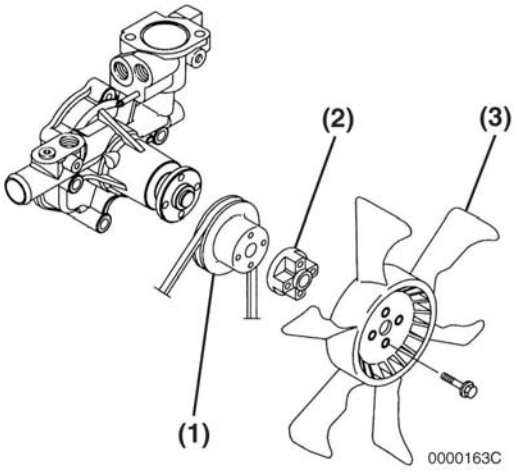


Figure 8-13

5. Inspect the condition of the V-belt. There must be clearance **(Figure 8-14, (1))** between the V-belt and the bottom of the pulley groove. If there is no clearance **(Figure 8-14, (2))** between the V-belt and the bottom of the pulley groove, replace the V-belt.

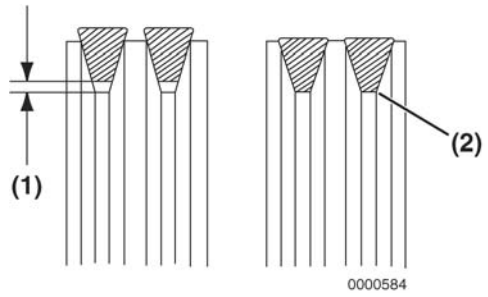


Figure 8-14

6. Reinstall the V-belt. Tighten the V-belt to the proper tension. See Check and Adjust Cooling Fan V-Belt on page 47.

7. Reinstall and tighten the drain plug or close the drain cock in the radiator. Reinstall and tighten the engine block drain plug or reconnect the coolant hose at the oil cooler.

8. Fill the radiator and engine with engine coolant. See Drain, Flush and Refill Cooling System With New Coolant on page 59.

CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and/or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

Section 6. LUBRICATION SYSTEM

Before You Begin Servicing

⚠ WARNING

ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it. NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.

Failure to comply could result in death or serious injury..

⚠ WARNING

BURN HAZARD!

Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.

Failure to comply could result in death or serious injury.

⚠ WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap/dipstick and the surrounding area before you remove the cap.

NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

⚠ CAUTION

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.

CAUTION

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

Introduction

This section of the Service Manual describes the procedures necessary to service the 4TNV98 Trochoid oil pump.

See Replace Engine Oil and Engine Oil Filter on page 51 for engine oil and engine oil filter replacement procedures.

Oil Pump Service Information

Engine Oil Pressure - All Models

At Rated Engine RPM	At Low Idle Speed
2000 - 2600 RPM	
42 - 57 psi (0.29 - 0.39 MPa; 3.0 - 4.0 kgf/cm²)	All Models 8.8 psi (0.06 MPa 0.6 kfg/cm²) or greater

Outer Rotor Outside Clearance - All Models

Standard	Limit	Reference Page
0.0039 - 0.0061 in. (0.100 - 0.155 mm)	0.0098 in. (0.25 mm)	Check Outer Rotor Outside Clearance on page 216

Outer Rotor Side Clearance - All Models

Standard	Limit	Reference Page
0.0020 - 0.0039 in. (0.05 - 0.10 mm)	0.0059 in. (0.15 mm)	Check Outer Rotor Side Clearance on page 217

Outer Rotor to Inner Rotor Tip Clearance - All Models

Standard	Limit	Reference Page
–	0.0063 in. (0.16 mm)	Outer Rotor to Inner Rotor Tip Clearance on page 217

Rotor Shaft Clearance

Model	Inspection Item	Standard	Limit	Reference Page
4TNV98	Gear Case Bearing I.D.	0.5110 - 0.5126 in. (12.980 - 13.020 mm)	0.5138 in. (13.05 mm)	Check Rotor Shaft Clearance on page 216
	Rotor Shaft O.D.	0.5100 - 0.5108 in. (12.955 - 12.975 mm)	0.5096 in. (12.945 mm)	
	Rotor Clearance	0.0014 - 0.0026 in. (0.035 - 0.065 mm)	0.0041 in. (0.105 mm)	
4TNE98	Gear Case Bearing I.D.	0.5110 to 0.5126 in. (12.980 - 13.020 mm)	0.5138 in. (13.05 mm)	Check Rotor Shaft Clearance on page 216
	Rotor Shaft O.D.	0.5089 to 0.5106 in. (12.925 - 12.970 mm)	0.5085 in. (12.915 mm)	
	Rotor Clearance	0.0004 to 0.0026 in. (0.010 to 0.065 mm)	0.0041 in. (0.105 mm)	

Lubrication System Diagram

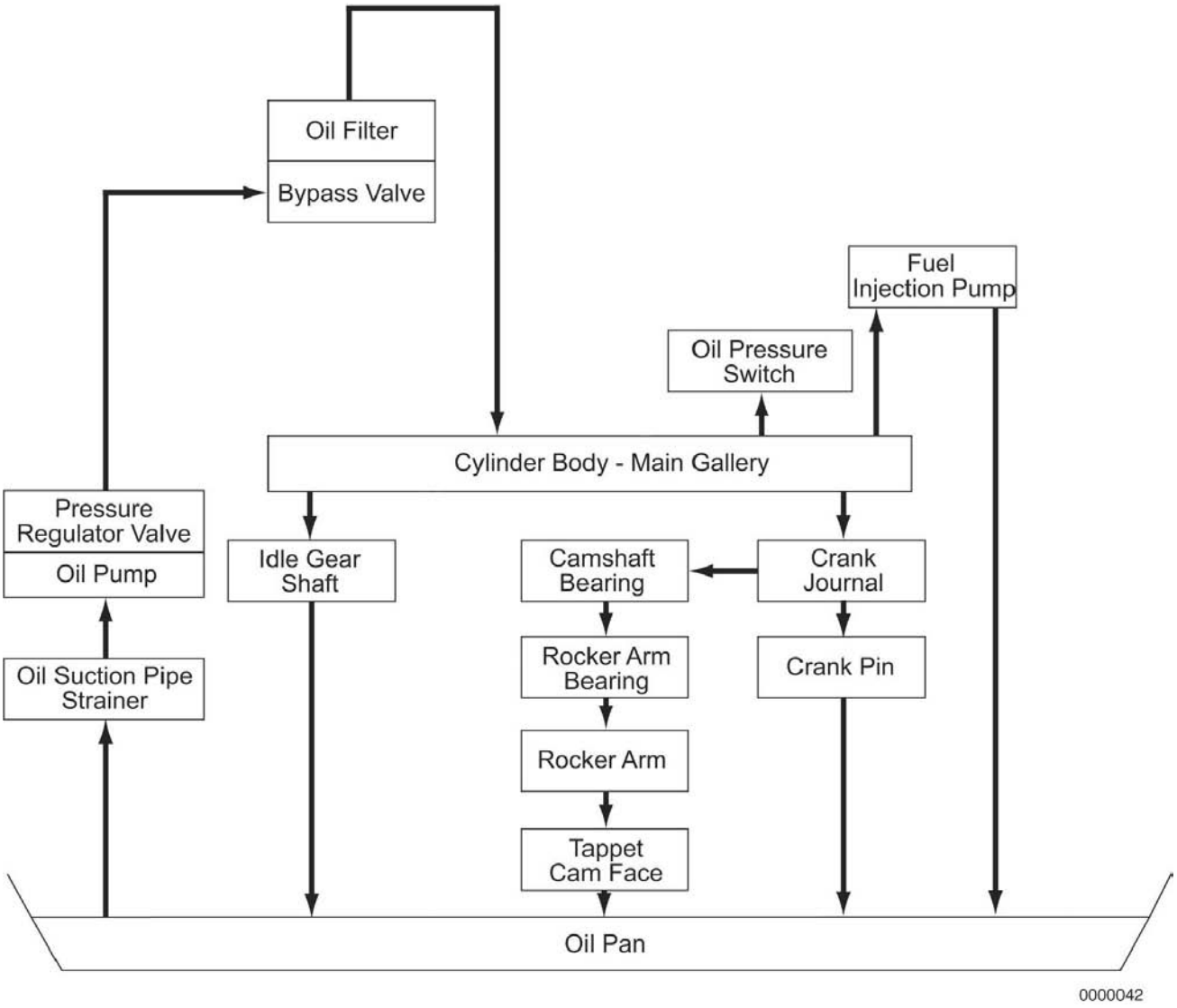


Figure 9-1

Checking Engine Oil Pressure

Perform an engine oil pressure check if there is any indication of low oil pressure such as the oil pressure indicator is on or the oil pressure gauge indicates low oil pressure. See Engine Oil Pressure - All Models on page 212.

1. Disconnect the wire lead from the oil pressure switch or sending unit (Figure 9-2, (1)).

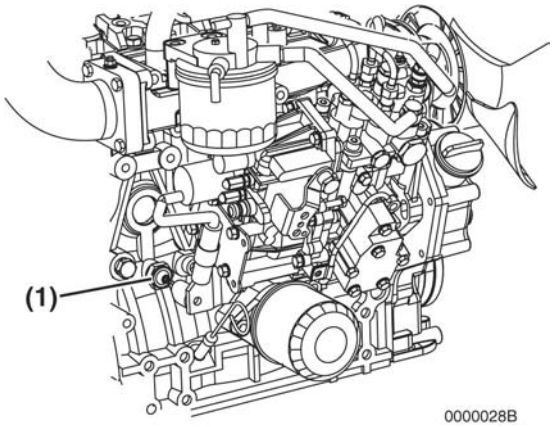


Figure 9-2

2. Remove the oil pressure switch.

3. Install a mechanical oil pressure gauge in the oil pressure switch port.

4. Start the engine:

- If the mechanical oil pressure test gauge indicates good oil pressure, replace the faulty oil pressure switch or sending unit, or faulty machine oil pressure gauge in instrument panel.
- If the mechanical oil pressure test gauge indicates low oil pressure, troubleshoot the lubrication system to locate the cause of the low oil pressure. See Troubleshooting Charts on page 190. Repair as necessary.

Trochoid Oil Pump

Oil Pump Components

The oil pump on these model engines is located in the front gear case and is driven by the same gear train that drives the camshaft and fuel injection pump. You must remove the front gear case cover to gain access to the oil pump.

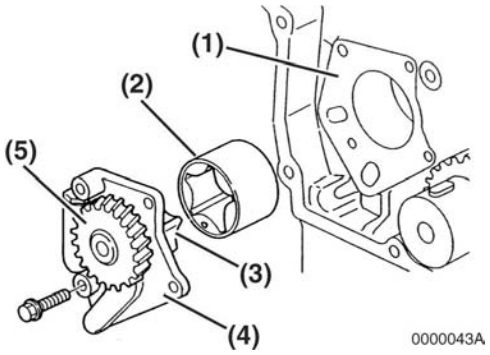


Figure 9-14

(1) Gear Case Housing.
(2) Outer Rotor.
(3) Inner Rotor.
(4) Cover Plate.
(5) Drive Gear.

Disassembly of Oil Pump

CAUTION

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

Remove the engine cooling fan guard (if equipped), engine cooling fan **(Figure 9-15, (3))**, spacer **(Figure 9-15, (2))**, engine coolant pump V-pulley **(Figure 9-15, (1))** and V-belt.

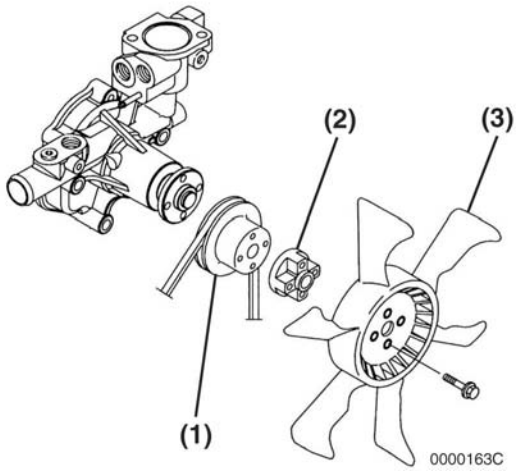


Figure 9-15

1. Remove the crankshaft pulley and the gear case cover. See Removal of Timing Gear Case Cover on page 111.

2. Remove the oil pump assembly bolts. Remove the oil pump assembly **(Figure 9-16, (1))** from the gear case housing **(Figure 9-16, (2))**.

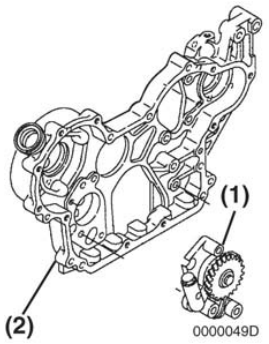


Figure 9-16

Cleaning and Inspection

Wash the oil pump, oil pressure regulator and oil pump cavity. Inspect for wear or damage. Replace as necessary.

⚠ CAUTION

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.

Check Outer Rotor Outside Clearance

Determine the outside clearance of the outer rotor. Insert a feeler gauge between the outer rotor **(Figure 9-17, (1))** and gear case oil pump cavity **(Figure 9-17, (2))**.

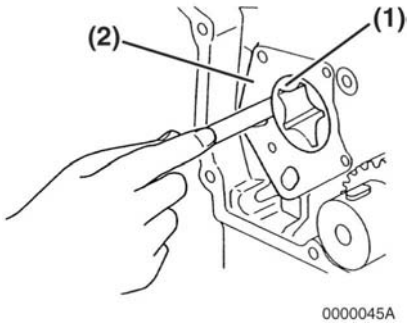


Figure 9-17

Record the measurement(s) and see Check Outer Rotor Outside Clearance on page 236 for the service limits.

Outer Rotor to Inner Rotor Tip Clearance

Determine the outer rotor to inner rotor tip clearance. Insert a feeler gauge between the top of an inner rotor tooth **(Figure 9-18, (1))** and the top of an outer rotor tooth **(Figure 9-18, (2))** and measure the clearance.

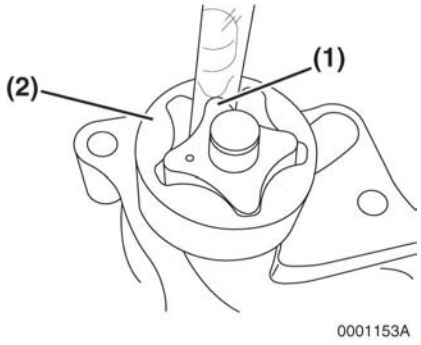


Figure 9-18

Record the measurement(s) and see Outer Rotor to Inner Rotor Tip Clearance on page 216 for the service limits.

Check Outer Rotor Side Clearance

Determine the side clearance of the outer rotor across the pump cavity. Measure the depression using a depth micrometer **(Figure 9-19, (1))**.

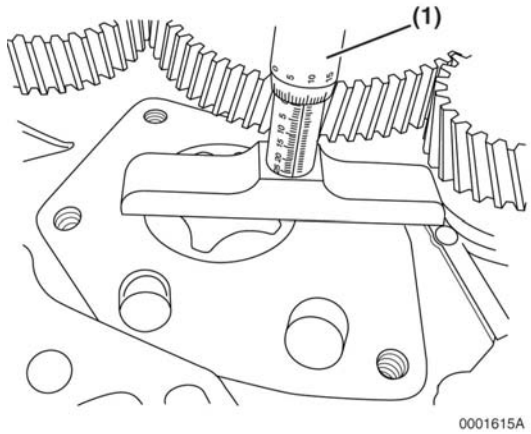


Figure 9-19

Record the measurement(s) and see Check Outer Rotor Side Clearance on page 217 for the service limits.

Check Rotor Shaft Clearance

Determine the rotor shaft clearance. Measure the outside diameter of the rotor shaft **(Figure 9-20, (1))** and the bore diameter in the gear case housing **(Figure 9-20, (2))**.

Calculate the difference between the two measurements to determine the clearance.

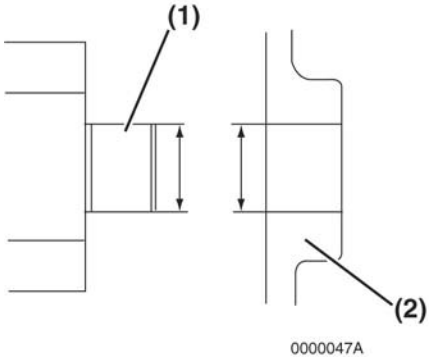


Figure 9-20

Record the measurement(s) and see Rotor Shaft Clearance on page 215 for the service limits.

Reassembly of Oil Pump

1. Lubricate the outer rotor and pump bore in the gear case with clean engine oil.

2. Reinstall the outer rotor in the gear case housing. The punch mark **(Figure 9-21, (1))** on the end of the outer rotor must face away from the gear case housing **(Figure 9-21, (2))**.

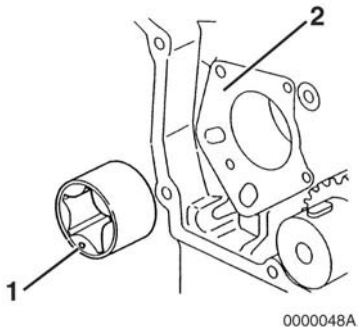


Figure 9-21

3. Reinstall the oil pump assembly **(Figure 9-22, (1))** into the gear case housing **(Figure 9-22, 2)**. Tighten the bolts to specified torque.

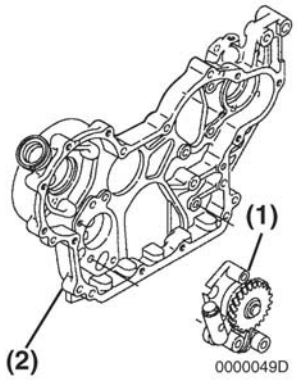


Figure 9-22

4. Reinstall the gear case cover and crankshaft pulley. See Installation of Gear Case Cover on page 137.

5. Reinstall the engine coolant pump V-pulley **(Figure 9-23, (1))**, spacer **(Figure 9-23, (2))**, engine cooling fan **(Figure 9-23, (3))** and engine cooling fan guard (if equipped).

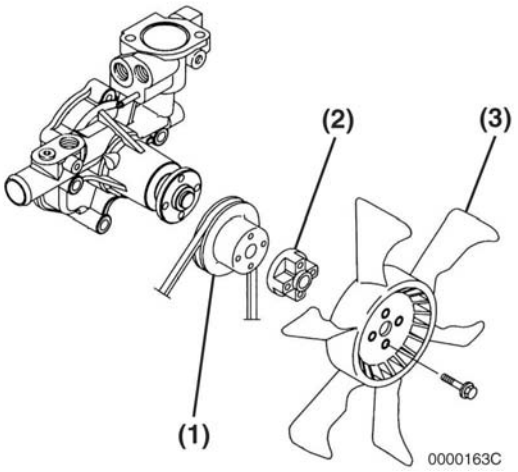


Figure 9-23

6. Reinstall the V-belt. Tighten the V-belt to the proper tension as described in Check and Adjust Cooling Fan V-Belt on page 47.

Section 7. STARTER MOTOR

Before You Begin Servicing

⚠ WARNING

ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it.

NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.

Failure to comply could result in death or serious injury.

⚠ WARNING

SHOCK HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

⚠ WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

⚠ CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

CAUTION

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test.

CAUTION

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated on the wiring diagram. The starter motor will malfunction or break down if the resistance is higher than the specified value.

CAUTION

The starter motor is water-proofed according to JIS D 0203, R2 which protects the motor from rain or general cleaning. Do not use high-pressure wash or submerse the starter motor in water.

CAUTION

Use a specialized battery charger to recharge a battery with a voltage of 8volts or less. Booster starting a battery with a voltage of 8 volts or less will generate an abnormally high voltage and destroy electrical equipment.

Introduction

This section of the Service Manual covers the servicing of the starter motor. This starter motor is used in this section to show the service procedures for a representative starter motor. For specific part detail, see the Yanmar Parts Catalog for the engine you are working on.

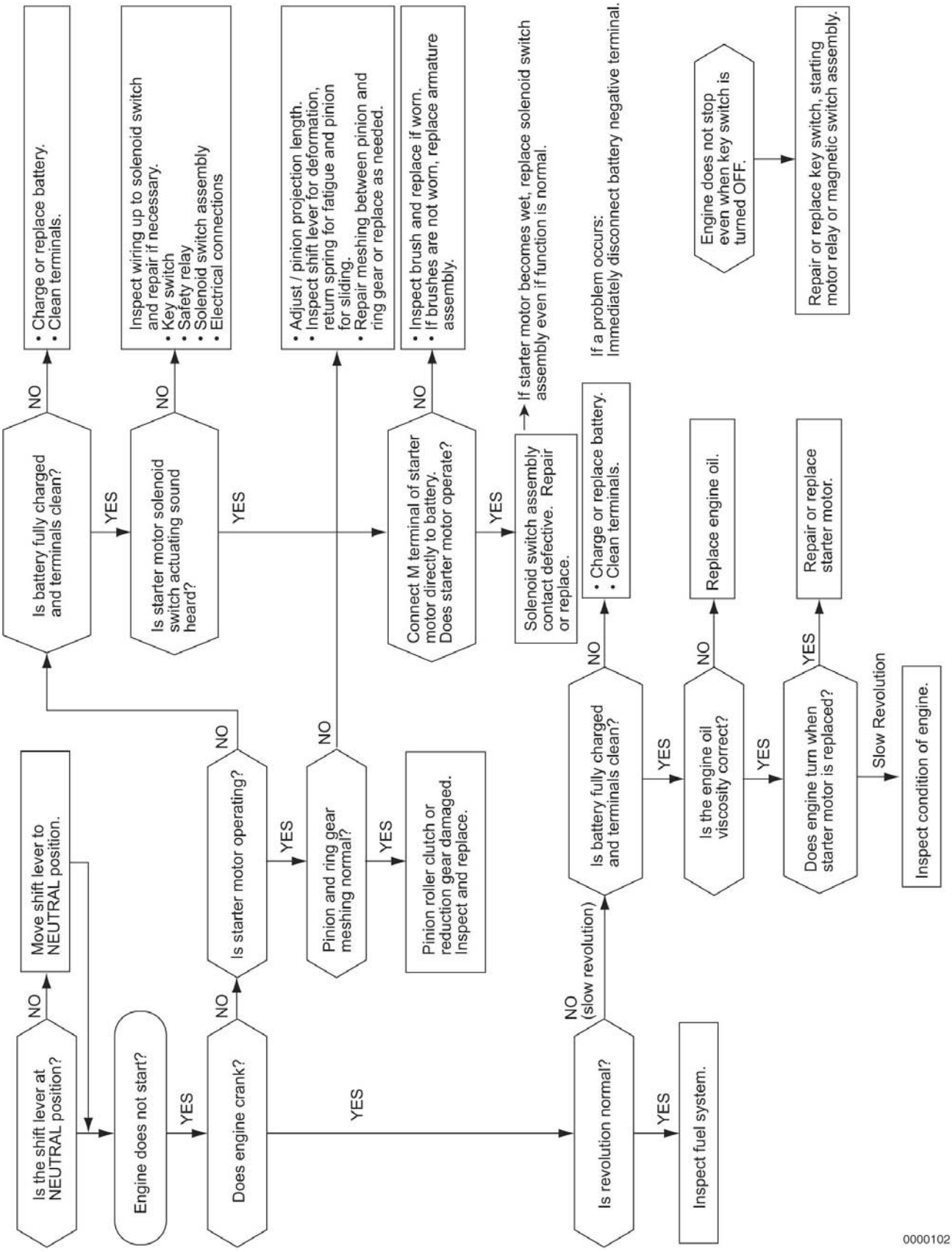
Starter Motor Information

DOOSAN Part Number	Mfg.	Mfg. Part Number	Specification	No Load			Loaded			
				Terminal Voltage	Amperage Draw	rpm	Terminal Voltage	Amperage Draw	Torque	rpm
A408417	Hitachi	S13-204	DC12V-3.1 hp (2.3 kW)	11	140A MAX	4100	7.7	400 Max	97 in.-lb (11.0 N·m; 1.1 kgf·m)	1400

Starter Motor Specifications

DOOSAN Part Number			A408417
Nominal Output			3.0 hp (2.3 kW)
Weight			12.1 lb(5.5 kg)
Revolution Direction (As Viewed From Pinion)			Clockwise
Engagement System			Magnetic Shift
No-load	Terminal Voltage / Current		11 V / 140 A max
	Revolution		4100 rpm (min-1)
Loaded	Terminal Voltage / Current		2.5 V / 1050 A max
	Torque		18 ft-lb (24.5 N·m; 2.5 kgf·m) minimum
Clutch System			Overrunning
Pinion Projection Voltage at 212°F (100 °C)			8.6 V max
Pinion DP or Module / Number of Teeth			M3/9
Difference (O-ring, Oil Seal)			Dry (none)
Application			Standard
Brush	Spring Force		7.868 lbf (35 N; 3.6 kgf)
	Height	Standard	0.591 in. (15 mm)
		Limit	0.354 in. (9 mm)
Magnetic Switch	Series Coil Resistance		0.27 Ω at 68°F (20°C)
	Shunt Coil Resistance		0.60 Ω at 68°F (20°C)
Commutator	Outside Diameter	Standard	1.437 in. (36.5 mm)
		Limit	1.398 in. (35 mm)
	Run-Out	Standard	0.001 in. (0.03 mm)
		Limit	0.008 in. (0.2 mm)
	Insulation Depth	Standard	0.020 - 0.031 in. (0.5 - 0.8 mm)
		Limit	0.008 in. (0.2 mm)
Armature	Run-Out	Standard	0.001 in. (0.03 mm)
		Limit	0.008 in. (0.02 mm)
Bearing Type	Armature Front	Nominal Number	6903DDU
	Armature Rear		608DDU
	Pinion Front		60004DDU
	Pinion Rear		6904DDU
Pinion Projection Length (Length L)			0.012 - 0.059 in. (0.3 - 1.5 mm)

Starter Motor Troubleshooting


Is the shift lever at NEUTRAL position?
NO
Move shift lever to NEUTRAL position.
Engine does not start?
YES
Does engine crank?
NO
Is starter motor operating?
NO
YES
Pinion and ring gear meshing normal?
NO
YES
Pinion roller clutch or reduction gear damaged. Inspect and replace.
YES
Is revolution normal?
NO (slow revolution)
YES
Inspect fuel system.
Is battery fully charged and terminals clean?
NO
• Charge or replace battery.
• Clean terminals.
YES
Is starter motor solenoid switch actuating sound heard?
NO
Inspect wiring up to solenoid switch and repair if necessary.
• Key switch
• Safety relay
• Solenoid switch assembly
• Electrical connections
YES
• Adjust / pinion projection length.
• Inspect shift lever for deformation, return spring for fatigue and pinion for sliding.
• Repair meshing between pinion and ring gear or replace as needed.
Connect M terminal of starter motor directly to battery. Does starter motor operate?
NO
• Inspect brush and replace if worn.
• If brushes are not worn, replace armature assembly.
YES
Solenoid switch assembly contact defective. Repair or replace.
If starter motor becomes wet, replace solenoid switch assembly even if function is normal.
Is battery fully charged and terminals clean?
NO
• Charge or replace battery.
• Clean terminals.
If a problem occurs: Immediately disconnect battery negative terminal.
YES
Is the engine oil viscosity correct?
NO
Replace engine oil.
YES
Does engine turn when starter motor is replaced?
YES
Repair or replace starter motor.
Slow Revolution
Inspect condition of engine.
Engine does not stop even when key switch is turned OFF.
Repair or replace key switch, starting motor relay or magnetic switch assembly.
0000102

Starter Motor Components

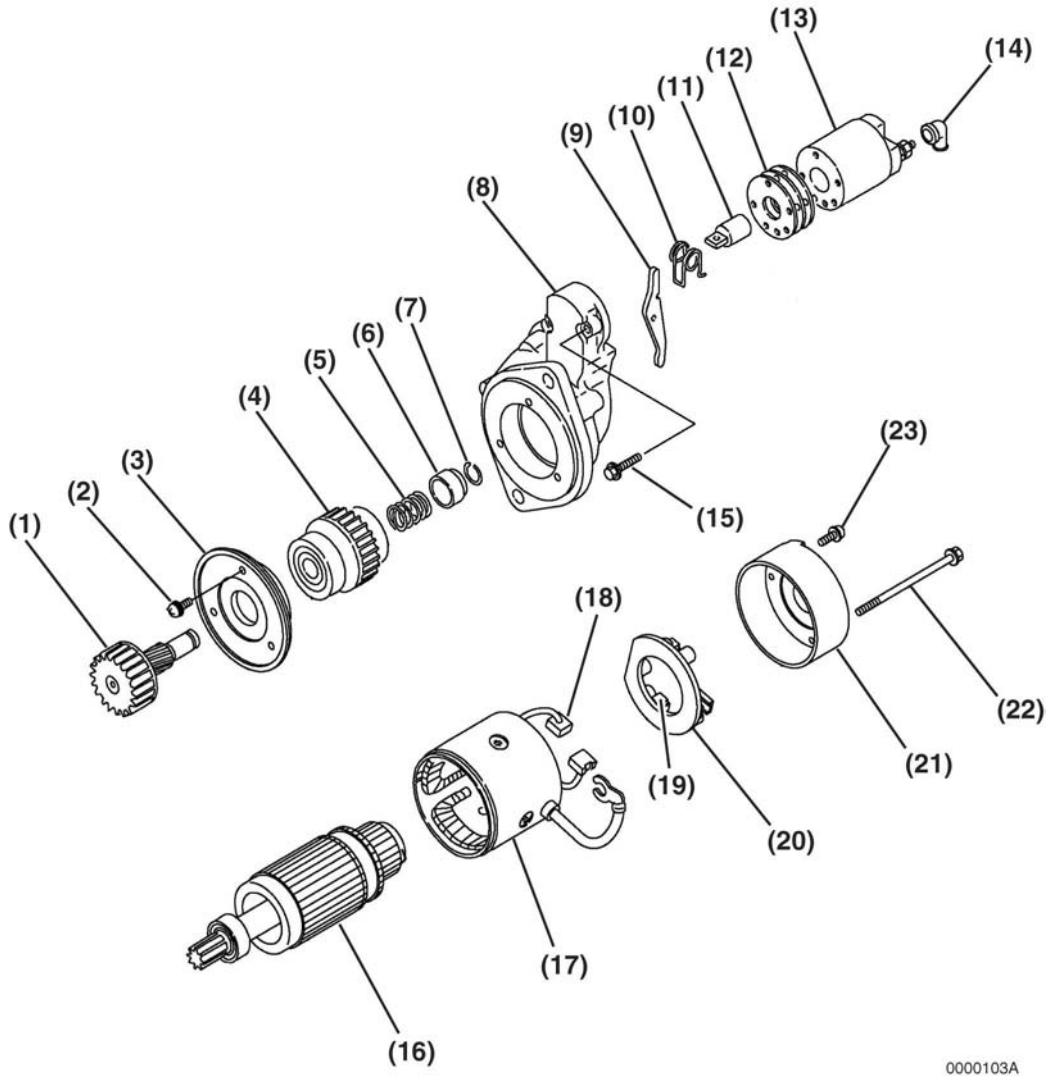


Figure 11-1

(1) Pinion Shaft. (2) M4 Bolts (3 used). (3) Bearing Retainer. (4) Pinion Clutch Assembly. (5) Return Spring. (6) Pinion Stop.
(7) Retaining Ring. (8) Gear Housing. (9) Shift Lever. (10) Torsion Spring. (11) Plunger. (12) Dust Covers (Shims).
(13) Magnetic Switch Assembly (Solenoid). (14) Cover. (15) M6 Bolts (2 used). (16) Armature Assembly. (17) Field Coil Assembly.
(18) Positive (+) Brushes. (19) Negative (-) Brushes. (20) Brush Holder Assembly. (21) Rear Cover. (22) M5 Through Bolts. (2 used).
(23) M4 Bolts (2 used)

Starter Motor

⚠ WARNING

SHOCK HAZARD!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.

Note: While starter motor design varies between models, the basic repair procedures are the same. The following procedures are typical and may differ from the stater being serviced.

Removal of Starter Motor

1. Disconnect the battery cables at the battery, negative (-) cable first.

2. Remove the electrical wires from the magnetic switch assembly.

3. Remove the starter mounting bolts **(Figure 11-2, (1))**. Remove the starter motor from the flywheel housing.

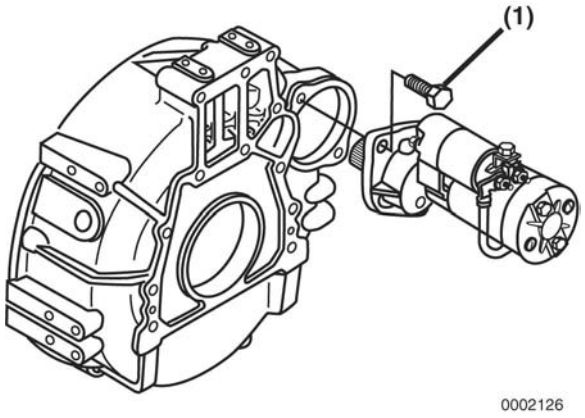


Figure 11-2

Disassembly of Starter Motor

1. Loosen the M8 nut from the magnetic switch (solenoid) assembly **(Figure 11-3)**. Disconnect the wire from the magnetic switch.

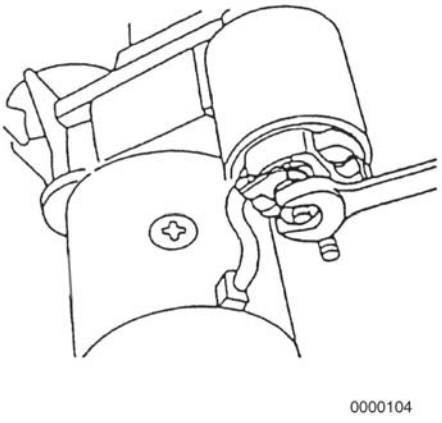


Figure 11-3

2. Remove the two M4 bolts **(Figure 11-4, (1))** securing the rear cover **(Figure 11-4, (2))** to the brush holder assembly **(Figure 11-4, (3))**.

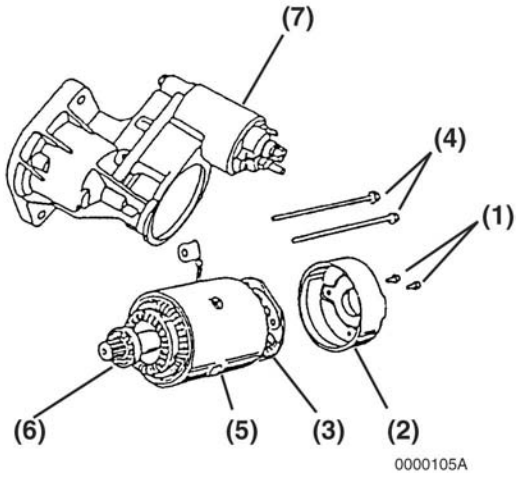


Figure 11-4

3. Remove the two M5 through bolts **(Figure 11-4, (4))**. Separate the rear cover **(Figure 11-4, (2))**, field coil assembly **(Figure 11-4, (5))** with the armature assembly **(Figure 11-4, (6))** from the gear housing **(Figure 11-4, (7))**.

4. Pull the brush springs up using a brush spring puller. On the negative (-) side, bring the brush spring into contact with the side of the brush for lifting from the commutator surface. On the positive (+) side, remove the brush from the brush holder assembly **(Figure 11-5, (1))**.

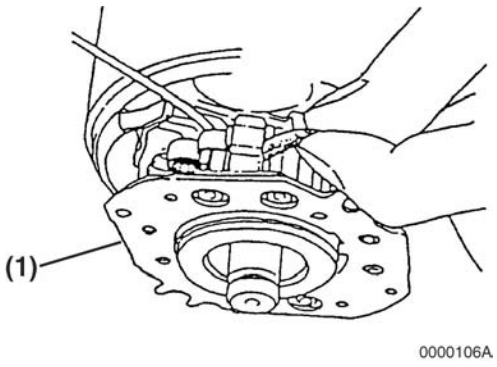


Figure 11-5

5. Remove the brush holder assembly **(Figure 11-6, (1))** from the armature assembly **(Figure 11-6, (3))**.

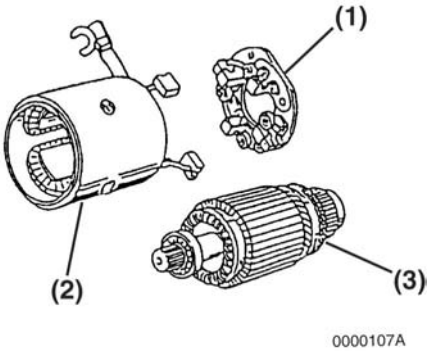


Figure 11-6

6. Pull the armature assembly **(Figure 11-6, (3))** out from the field coil assembly **(Figure 11-6, (2))**.

7. Remove the two M6 bolts **(Figure 11-7, (1))** retaining the magnetic switch assembly **(Figure 11-7, (2))** to the gear housing. Remove the magnetic switch assembly, dust cover(s) **(Figure 11-7, (3))** and torsion spring **(Figure 11-7, (4))** from the gear housing.

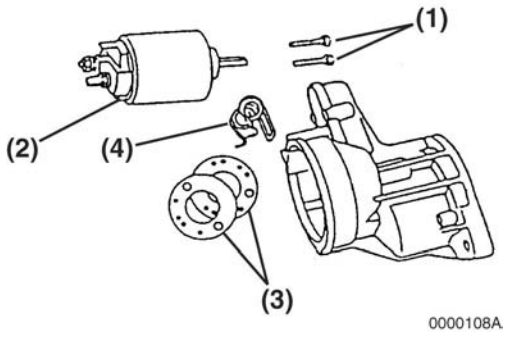


Figure 11-7

8. Disassemble the dust cover **(Figure11-8, (3))** and shift the lever **(Figure11-8, (4))** from the gear housing.

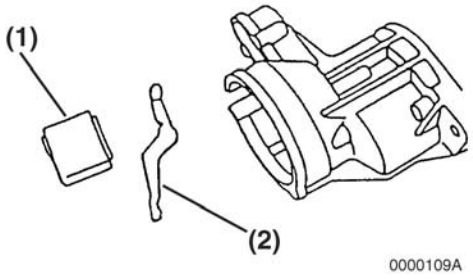


Figure 11-8

9. Remove the three M4 bolts **(Figure 11-9, (1))** securing the bearing retainer assembly **(Figure 11-9, (2))** to the gear housing. Remove the bearing retainer assembly from the gear housing.

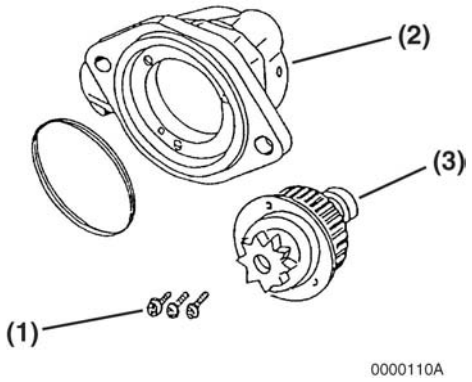


Figure 11-9

10. Remove the pinion clutch assembly **(Figure 11-9, (3))** from the bearing retainer assembly.

11. Using a flat-blade screwdriver, remove the retaining ring **(Figure 11-10, (1))** from the shaft of the pinion.

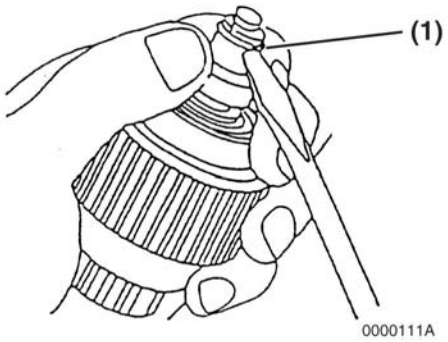


Figure 11-10

12. Disassemble the pinion stop **(Figure 11-11, (3))**, return spring **(Figure 11-11, (4))**, pinion clutch assembly **(Figure 11-11, (1))**, and pinion shaft **(Figure 11-11, (5))**.

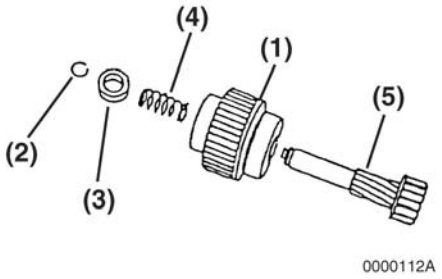


Figure 11-11

Cleaning and Inspection

Armature

Commutator Surface Inspection

If the commutator surface is rough, polish the surface with a #500 to #600 emery cloth **(Figure 11-12)**.

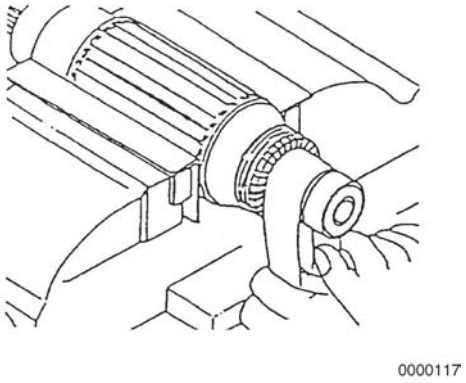


Figure 11-12

Measure Commutator Outside Diameter

Measure the commutator outside diameter **(Figure11-13)**. Replace the armature if the measurement is less than the limit.

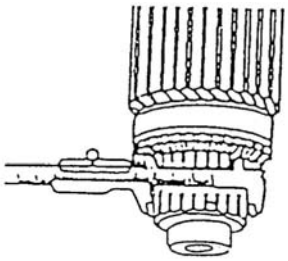


Figure 11-13

See Starter Motor Specifications on page 222 for the service limit.

Measure Commutator Insulation Depth

Measure the depth of the insulating material **(Figure11-14, (1))** between commutator segments **(Figure11-14, (2))**. If the depth measures less than the limit, use a hacksaw blade **(Figure11-14, (3))** to remove the insulating material until the depth is within the limit.

A normal commutator condition is indicated in **(Figure11-14, (4))**. An abnormal commutator condition is indicated in **(Figure11-14, (5))**.

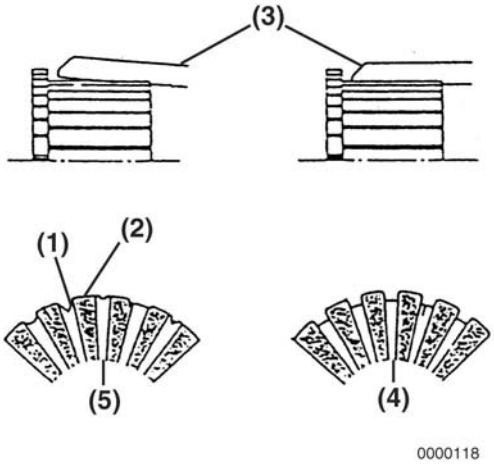


Figure 11-14

See Starter Motor Specifications on page 222 for the service limit.

Armature Coil Continuity Test

Check for continuity between the commutator segments using a multimeter **(Figure 11-15)**. The multimeter should indicate continuity.

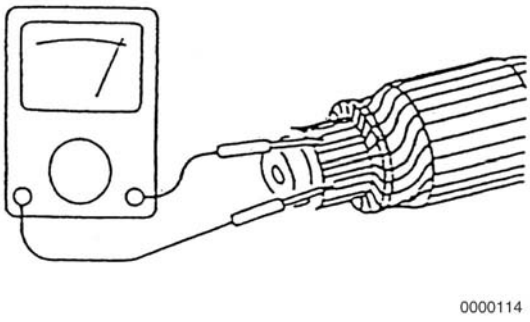


Figure 11-15

If the multimeter does not indicate continuity, replace the armature.

Armature Coil Insulation Test

Check for continuity between a commutator segment and the shaft or armature using a multimeter **(Figure11-16)**. The multimeter should not indicate continuity.

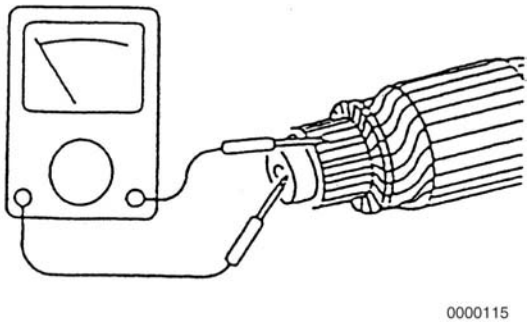


Figure 11-16

If the multimeter indicates continuity, replace the armature.

Measure Armature and Commutator Run-Outs

Measure the armature core run-out and the commutator run-out using a dial indicator **(Figure 11-17)**. Replace the armature if either of the measurements is less than the limit.

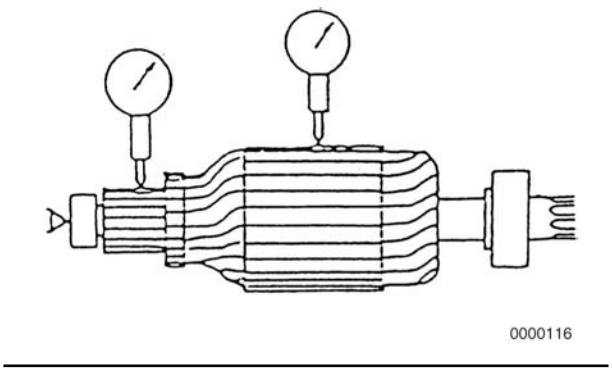


Figure 11-17

See Starter Motor Specifications on page 222 for the service limit.

Field Coil

Field Coil Continuity Test

Check for continuity between the field coil terminals using a multimeter **(Figure11-18)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the field coil assembly.

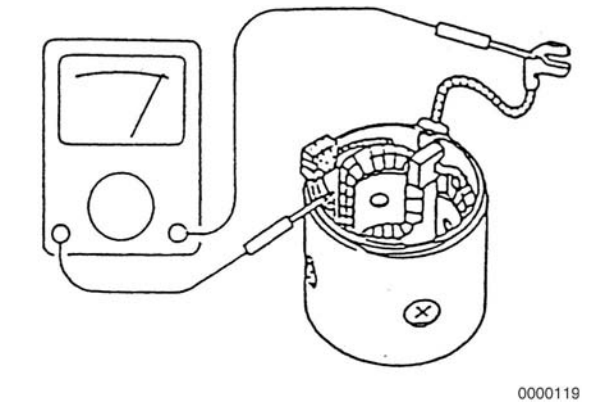


Figure 11-18

Field Coil Insulation Test

Check for continuity between the field coil terminal and the yoke using a multimeter **(Figure11-19)**. The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the field coil assembly.

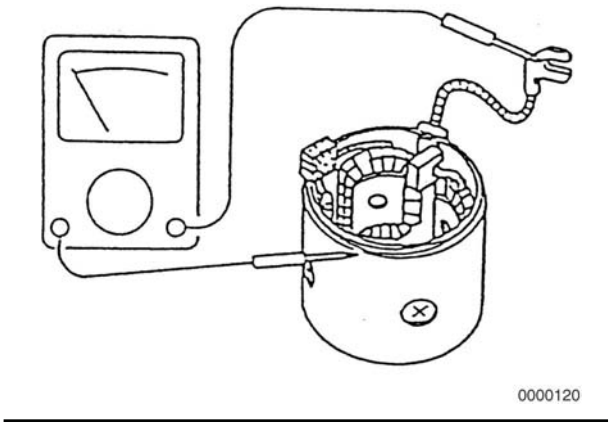


Figure 11-19

Measure Brush Length

Measure the length of the brush **(Figure11-20)**. Replace the brush if the length is less than the limit.

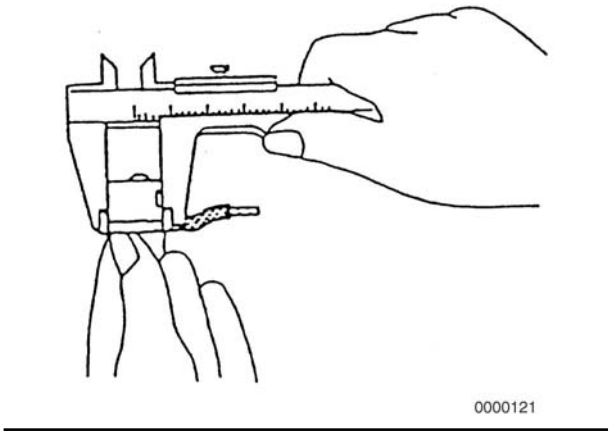


Figure 11-20

See Starter Motor Specifications on page 222 for the service limit.

Magnetic Switch

If the starter motor becomes wet, replace the magnetic switch even if the magnetic switch assembly function is normal.

Shunt Coil Continuity Test

Check for continuity between the “S” terminal and the switch body using a multimeter **(Figure11-21)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

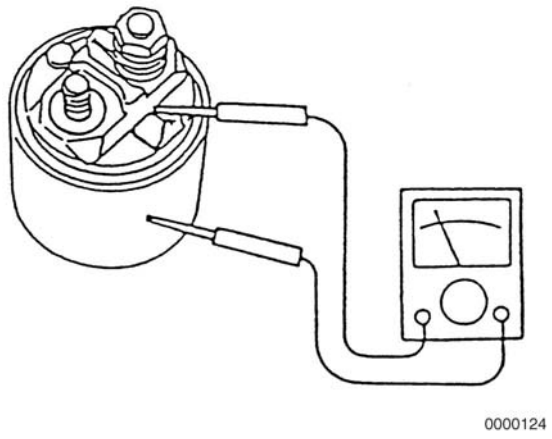


Figure 11-21

Series Coil Continuity Test

Check for continuity between the “S” and “M” terminals using a multimeter **(Figure11-22)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

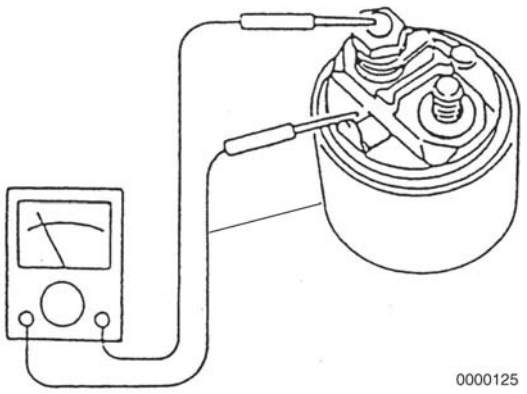


Figure 11-22

Coil Resistance Test

See Starter Motor Specifications on page 222 for the service limit.

Contact Continuity Test

Depress the plunger at the bottom of the magnetic switch. Check for continuity between the “B” and “M” terminals using a multimeter **(Figure11-23)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

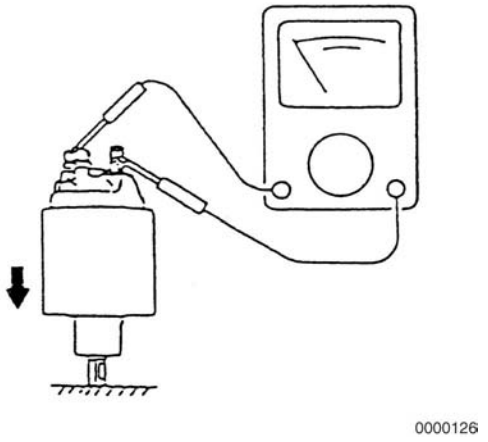


Figure 11-23

Pinion Clutch Assembly

Pinion Clutch Assembly Inspection

Manually rotate the pinion clutch assembly in the drive direction **(Figure11-24)**. It should rotate freely in the drive direction and is locked by turning it in the opposite direction. Replace the pinion clutch assembly if the results are different.

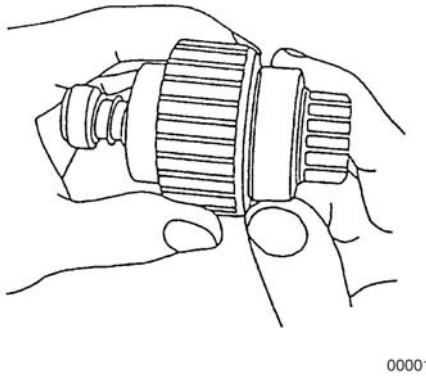


Figure 11-24

Slide the pinion clutch assembly on the shaft. It should slide smoothly on the shaft **(Figure11-25)**. Rust, too much grease or damage could prevent the pinion clutch from sliding smoothly. If the pinion clutch assembly does not slide smoothly, clean the shaft and pinion clutch assembly or replace the damaged component.

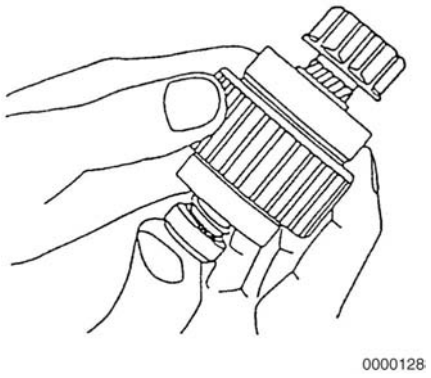


Figure 11-25

Ball Bearing Inspection

Rotate each ball bearing while holding the pinion clutch assembly **(Figure11-26)**. Replace the ball bearing if it does not rotate smoothly or has excessive play.

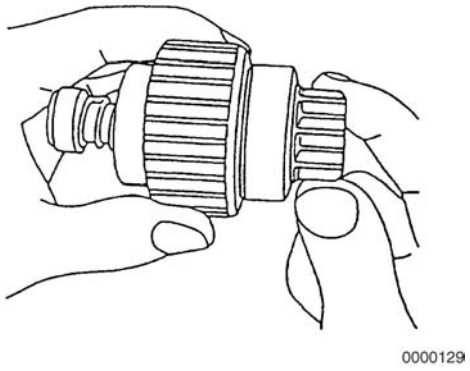


Figure 11-26

Reassembly of Starter Motor

1. Apply the appropriate starter bendix grease (obtain locally) to the pinion shaft. Reassemble the pinion shaft **(Figure 11-27, (5))**, pinion clutch assembly **(Figure 11-27, (1))**, return spring **(Figure 11-27, (4))** and pinion stop **(Figure 11-27, (3))**. Reinstall the retaining ring **(Figure 11-27, (2))** in the groove in the pinion shaft. Slide the piston stop over the retaining ring.

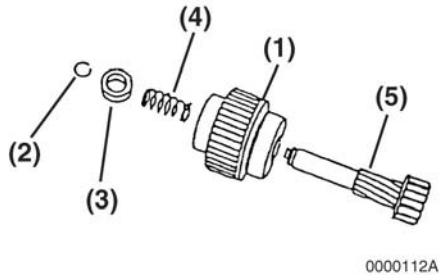


Figure 11-27

2. Reinstall the pinion clutch assembly into the bearing retainer assembly.

3. Reinstall the bearing retainer assembly and pinion assembly to the gear housing. Reinstall and tighten the three M_4 bolts.

4. Apply a small amount of high temperature lithium grease (obtain locally) to the sliding portions of the shift lever **(Figure 11-28, (1))**. Reassemble the torsion spring **(Figure 11-28, (2))**, shift lever and dust cover(s) **(Figure 11-28, (3))**, plunger **(Figure 11-28, 4)** and magnetic switch assembly **(Figure 11-28, (5))**.

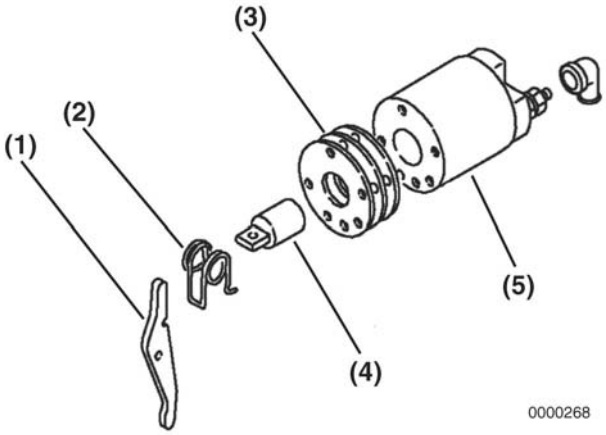


Figure 11-28

5. Reassemble the magnetic switch assembly to the gear housing. Pry the pinion away from the gear housing to allow installation of the magnetic switch assembly **(Figure 11-29)**.

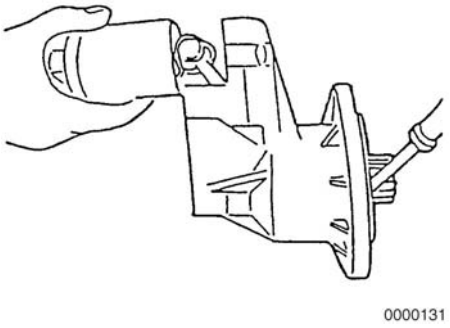


Figure 11-29

6. Secure the magnetic switch assembly to the gear housing using the two M_6 bolts.

7. Carefully install the armature assembly **(Figure11-30, (1))** into the field coil assembly **(Figure11-30, (2))**.

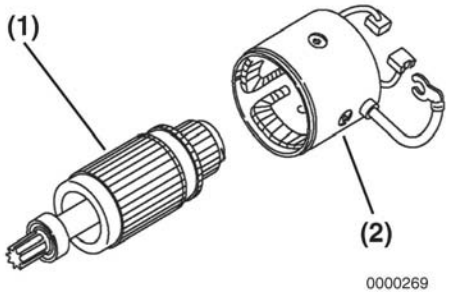


Figure 11-30

8. Position the brush springs in brush holders **(Figure 11-31)**. Reinstall the brushes in the brush holders. Reversing the brushes will cause the starter motor to turn backwards.

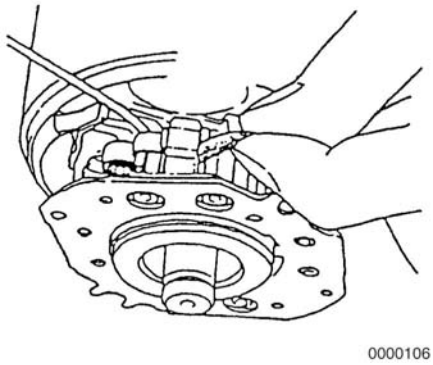


Figure 11-31

9. Carefully install the brush holder assembly to the armature assembly.

10. Reinstall the field coil assembly with the armature assembly to the gear housing.

11. Reinstall the rear cover to the brush holder assembly. Securely tighten the two bolts.

12. Reinstall the two M_4 through bolts **(Figure 11-32)**. Securely tighten the through bolts. Reconnect the wire to the magnetic switch assembly. Tighten the M_8 nut. Reinstall the cover over the connection.

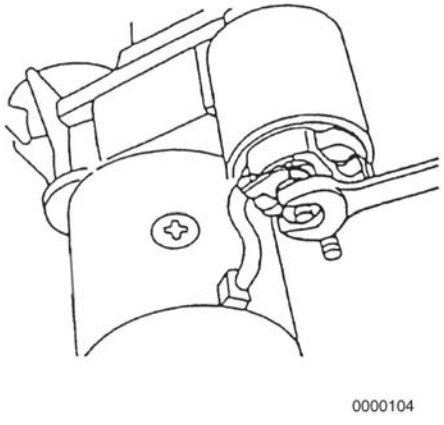


Figure 11-32

Check Pinion Projection Length

1. Connect the positive (+) lead from a battery to the “S” terminal.

2. Connect the negative (-) lead to the “M” terminal.

3. Lightly pull the pinion away from the gear housing.

4. Turn the switch ON and measure the pinion moving distance L in the thrust direction **(Figure 11-33)**. Perform this test within 10 seconds. See Starter Motor Specifications on page 222 for the service limit.

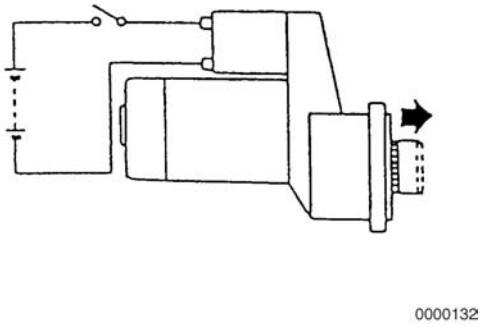


Figure 11-33

5. If the measured L dimension is outside the standard range, adjust the dust covers to obtain the standard range. Dust covers **(Figure 11-34, (1))** are available in 0.020 in (0.5 mm) and 0.031 in (0.8 mm) thicknesses.

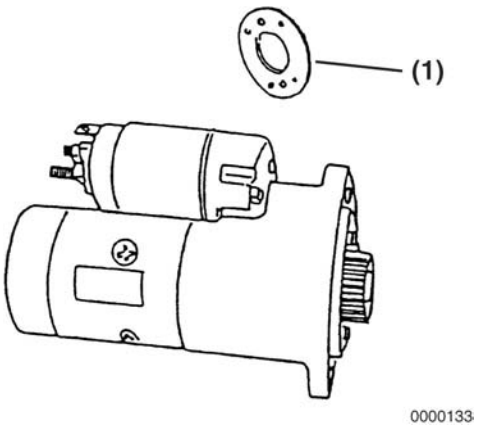


Figure 11-34

No-Load Test

Test the characteristics of the starter motor by performing a no-load test.

CAUTION

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test.

1. Secure the starting motor in a vise or other suitable fixture.

2. Connect an ammeter **(Figure 11-35, (1))** in series between the battery positive (+) terminal **(Figure 11-35, (2))** and the main positive (+) terminal **(Figure 11-35, (3))** on the starter motor.

Note: The ammeter and all wire leads used in this test must have a capacity equal to or greater than the amperage draw specification for the starter motor being tested.

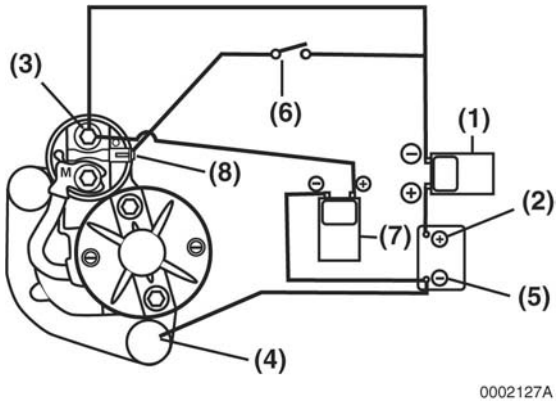


Figure 11-35

3. Connect a wire lead between the mounting base of the starter motor **(Figure 11-35, (4))** and the battery negative terminal **(Figure 11-35, (5))**.

4. Connect a voltmeter **(Figure 11-35, (7))** to the battery negative (-) terminal **(Figure 11-35, (5))** and the main positive (+) battery terminal **(Figure 11-35, (3))** on the starter motor.

5. Install a switch **(Figure 11-35, (6))** in a circuit between the battery positive (+) terminal **(Figure 11-35, (2))** and the starter magnetic switch (solenoid) terminal **(Figure 11-35, (8))** on the starter motor.

6. Use a suitable tachometer to monitor the rpm of the starter.

7. Turn the switch to the ON position. Monitor the rpm, amperage draw and voltage. For test specifications, see page 221 for the appropriate starter motor.

Installation of Starter Motor

1. Reinstall the starter motor to the flywheel housing.

2. Reinstall the starter mounting bolts **(Figure 11-36, (1)).** Tighten the bolts to specification. See Tightening Torques for Standard Bolts and Nuts on page 25.

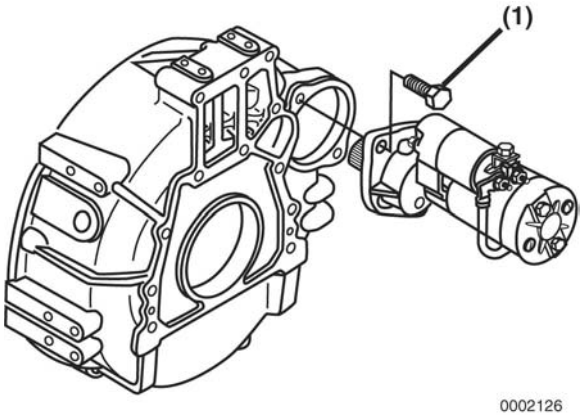


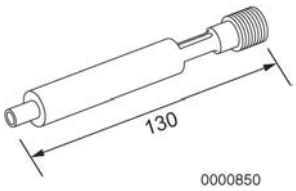
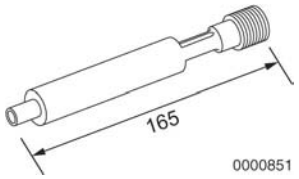
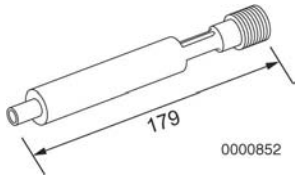
Figure 11-36

3. Reconnect the electrical wires to the magnetic switch assembly (solenoid). Be sure to place the cover over the battery positive (+) cable connection.

4. Reconnect the battery cables at the battery.

Section 8. TROUBLESHOOTING

Special Service Tools

Compression Gauge Kit	For measuring compression pressure Yanmar Gauge Set Part No. TOL-97190080	
	Adapter for direct injection 2-valve cylinder head Yanmar Adapter Part No. 119802-92950	
	Adapter for direct injection 4-valve cylinder head for 4TNV94L/98/98T Yanmar Adapter Part No. 129906-92950	
	Adapter for direct injection 4-valve cylinder head for 4TNV106(T) Yanmar Adapter Part No. 123907-92950	

Troubleshooting By Measuring Compression Pressure

Compression pressure drop is one of the major causes of increasing blow-by gas (engine oil contamination or increased engine oil consumption as a resultant phenomenon) or starting failure. The compression pressure is affected by the following factors:

1. Degree of clearance between the piston and cylinder

2. Degree of clearance at the intake / exhaust valve seat

3. Gas leak from the nozzle gasket or cylinder head gasket

The pressure will drop due to increased parts wear. Pressure drop reduces the durability of the engine.

A pressure drop may also be caused by a scratched cylinder or piston, dust entrance from the dirty air cleaner element or a worn or broken piston ring. Measure the compression pressure to determine the condition of the engine.

Compression Pressure Measurement Method

1. Warm up the engine.

2. Stop the engine. Remove the high-pressure fuel injection lines as an assembly from the engine. Remove the fuel injector from the cylinder to be measured. See Removal of Fuel Injectors on page 147.

⚠ CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible.

Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

3. Turn off the fuel supply valve in the fuel supply line. Disconnect the fuel injection pump stop solenoid at the connector. This prevents the fuel injection pump from injecting fuel during

4. Before installing the compression gauge **(Figure 14-1, (1))** adapter, crank the engine with the stop solenoid disconnected for a few seconds to clear the cylinder of any residual fuel.

5. Install a nozzle seat at the tip end of the compression gauge adapter. Install the compression gauge and the compression gauge adapter at the cylinder to be measured.

6. Crank the engine until the compression gauge reading is stabilized.

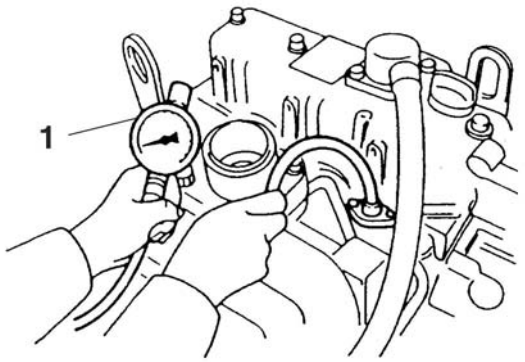


Figure 14-1

7. After performing the compression check remove the compression gauge and compression gauge adapter from the cylinder. Reinstall the fuel injector, high-pressure fuel injection lines, and reconnect the stop solenoid. *See Reassembly of* Fuel Injectors on page 165.

8. Turn on the fuel supply valve and reconnect the injection pump stop solenoid.

9. Prime the fuel system. Check for leaks. Test the engine. compression testing.

Standard Compression Pressure (Reference Value)

Engine Model	Compression Pressure at 250 rpm (250 min-1)		Deviation Between Cylinders
	Standard	Limit	
4TNV98	483 - 513 psi (3.33 - 3.53 MPa; 34 - 36 kgf/cm²)	384 - 414 psi (2.65 - 2.85 MPa; 27 - 29 kgf/cm²)	29 - 43 psi (0.2 - 0.3 MPa; 2 – 3 kgf/cm²)

Engine Speed and Compression Pressure (Use for Reference)

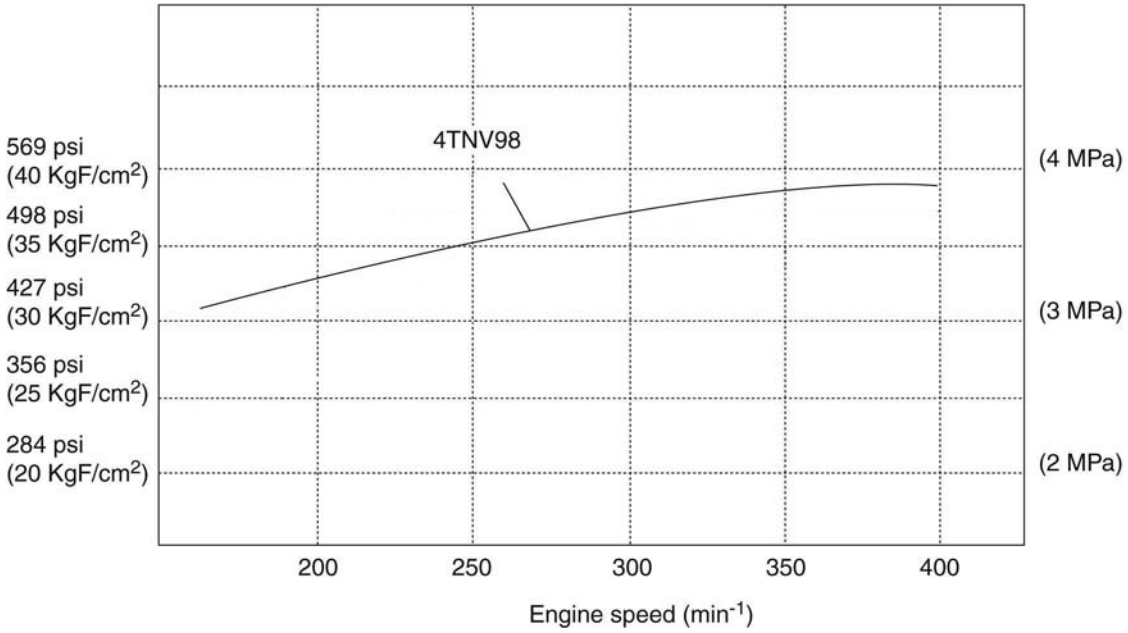


Figure 14-2

Engine Model	Compression Pressure at 250 rpm (250 min-1)		Deviation Between Cylinders
	Standard	Limit	
4TNE98	426 ± 15 psi (2.94 ± 0.1 MPa, 30 ± 1 kgf/cm²)	341 ± 15 psi (2.35 ± 0.1 MPa, 24 ± 1 kgf/cm²)	29 to 43 psi (0.2 to 0.3 MPa; 2 to 3 kgf/cm²)

Engine Speed and Compression Pressure (Use for Reference)

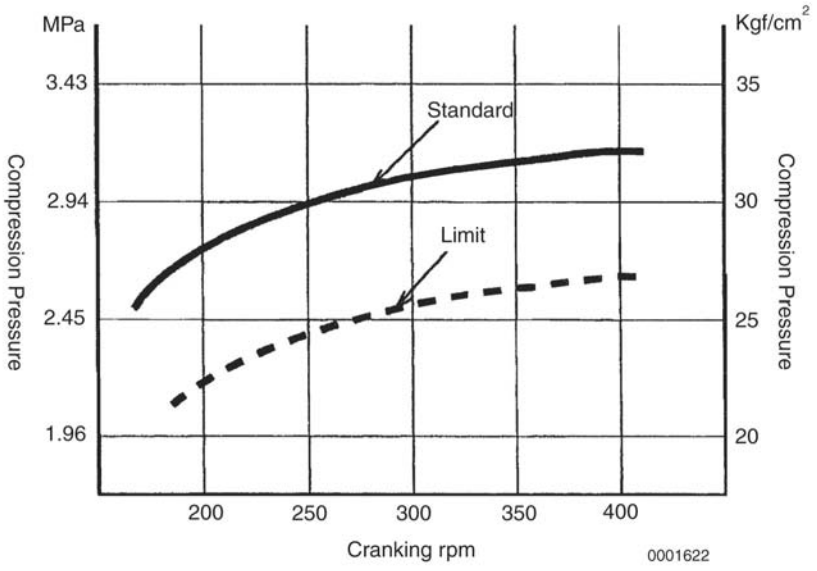


Figure 13-2

Measured Value and Troubleshooting

When the measured compression pressure is below the limit value, inspect each part by referring to the table below.

No	Item	Cause	Corrective Action
1	Air Cleaner Element	Clogged element	Clean the element.
		Broken element	Replace the element.
		Defect at element seal portion	
2	Valve Clearance	Excessive or no clearance	Adjust the valve clearance.
3	Valve Timing	Incorrect valve clearance	Adjust the valve clearance.
4	Cylinder Head Gasket	Gas leak from gasket	Replace the gasket.
			Retighten the cylinder head bolts to the specified torque.
5	Intake/ Exhaust Valve	Sticking valve	Replace the intake / exhaust valve.
	Valve Seat	Gas leak due to worn valve seat or foreign matter trapped in valve	Lap the valve seat.
6	Piston	Gas leak due to scratching or wear	Perform honing and use an oversized Piston Ring part.
	Piston Ring		
	Cylinder		

Quick Reference Table For Troubleshooting

The following table summarizes the general trouble symptoms and their causes. If any trouble symptom occurs, take corrective action before it becomes a serious problem so as not to shorten the engine service life.

Troubleshooting Charts

Engine System	Trouble Symptom / Cause	Starting Problem: Engine Does Not Start.	Starting Problem: Engine Starts But Stops Soon. – Exhaust Smoke: None	Starting Problem: Engine Starts But Stops Soon. – Exhaust Smoke: Little	Starting Problem: Engine Starts But Stops Soon. – Exhaust Smoke: Much	Insufficient Engine Output – Exhaust Color: Ordinary	Insufficient Engine Output – Exhaust Color: White	Insufficient Engine Output – Exhaust Color: Black	Poor Exhaust Color During Work: White	Poor Exhaust Color During Work: Black	High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging: During Idling	Engine Surging: During Work Operation	Excessive Engine Vibration	Difficulty In Returning to Low Speed	Excessive Fuel Consumption	Engine Oil: Excessive Oil Consumption	Engine Oil: Dilution by Diesel Fuel	Engine Oil: Oil with Water	Engine Oil: Low Oil Pressure	Excessive Blow-by Gas	Engine Coolant: Overheat	Engine Coolant: Low Water Temperature	Air Intake: Pressure Drop	Air Intake: Pressure Rise	Exhaust Temperature Rise	Corrective Action	Reference Page
Engine System	Improper Intake / Exhaust Valve Clearance	O	O			O						O																O	Adjust the Valve Clearance.	*See Measuring and Adjusting Valve Clearance on page 104.*
	Compression Leakage from Valve Seat					O		O		O		O					O					O				O		O	Lap the Valve Seat.	*See Valve Face and Valve Seat on page 96 for 2 valve head or Valve Face and Valve Seat on page 96 for 4 valve head.*
	Intake / Exhaust Valve Seizure	O		O	O		O		O			O		O	O				O				O					Correct or Replace Intake / Exhaust Valve.	*See Removal of Intake / Exhaust Valves on page 91.*
	Cylinder Head Gasket Blowout					O														O				O					Replace the Gasket.	*See Removal of Cylinder Head on page 91.*
	Seized or Broken Piston Ring	O		O			O		O			O		O	O				O	O			O				O	Replace the Piston Ring.	*See Reassembly of Pistons on page 127.*
	Worn Piston Ring, Piston or Cylinder	O		O			O		O										O	O			O					Perform Honing and Use Oversize Parts.	*See Honing and Boring on page 126.*
	Seized Crankpin Metal or Bearing	O	O									O		O	O	O												Repair or Replace.	*See Inspection of Crankshaft on page 124.*
	Improper Arrangement of Piston Ring Joints		O				O												O				O					Correct the Ring Joint Positions.	*See Reassembly of Pistons on page 127.*
	Reverse Assembly of Piston Rings						O		O										O				O					Reassemble Correctly.	*See Reassembly of Pistons on page 127.*
	Worn Crankpin and Journal Bearing					O						O		O	O	O						O						Measure and Replace.	*See Inspection of Crankshaft on page 124.*
	Loose Connecting Rod Bolt											O			O							O						Tighten to the Specified Torque.	*See Torque for Bolts and Nuts on page 73.*
	Foreign Matter Trapped in Combustion Chamber	O										O							O				O					Disassemble and Repair.	*See Disassembly of Engine on page 111.*
	Excessive Gear Backlash											O																Adjust Gear Mashing.	*See Checking Timing Gear Backlash on page 112.*
	Worn Intake / Exhaust Valve Guide						O												O				O					Measure and Replace.	*See Inspection of Valve Guides on page 94.*
	Governor Adjusted Incorrectly		O												O	O	O	O										Make Adjustment.	*See Check and Adjust the Governor Lever and Engine Speed Control on page 52.*
	Improper Open / Close Timing of Intake / Exhaust Valves	O					O	O	O	O		O																Adjust the Valve Clearance.	*See Measuring and Adjusting Valve Clearance on page 104.*

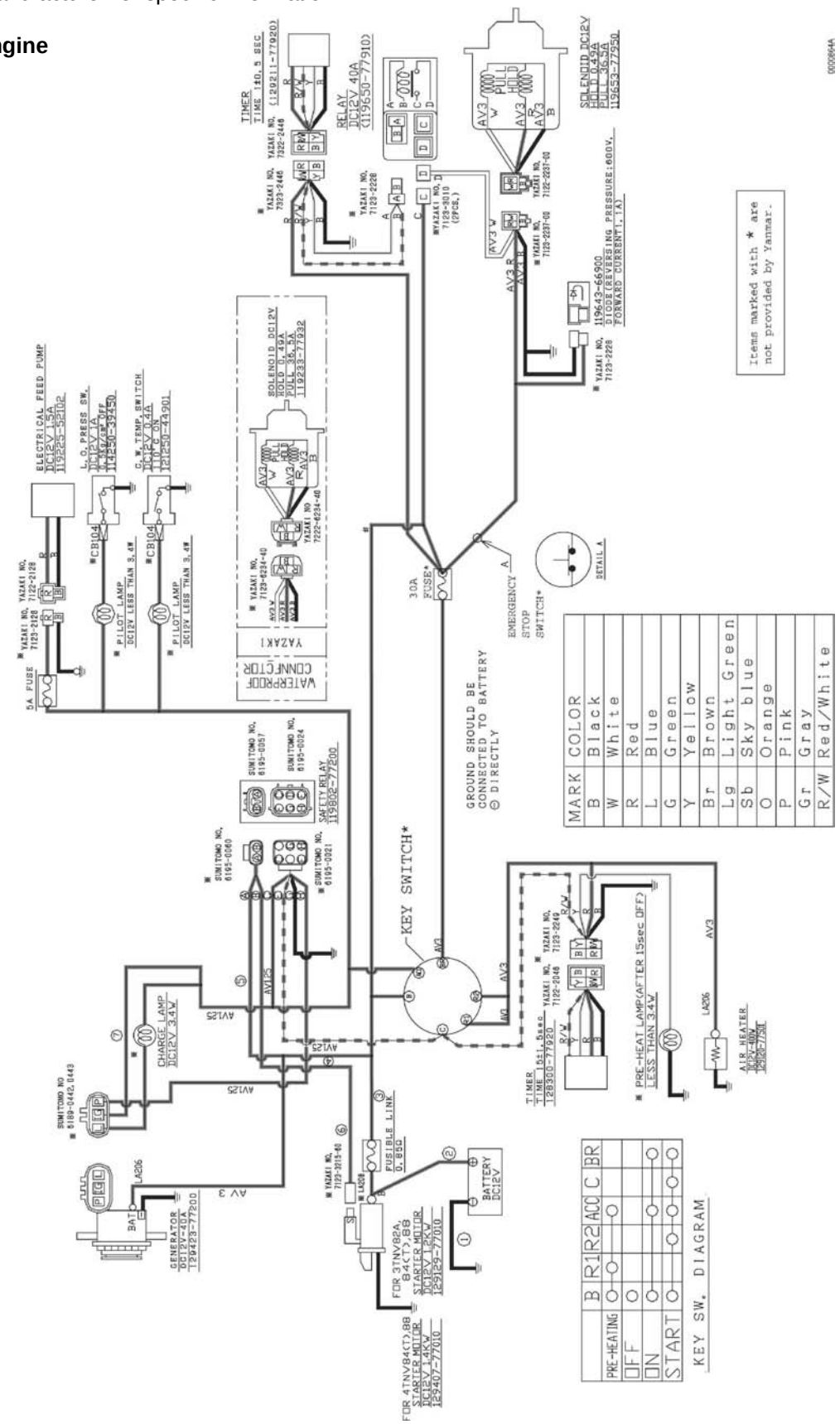
Trouble Symptom / Cause		Starting Problem			Insufficient Engine Output	Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Excessive Engine Vibration	Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil					Engine Coolant		Air Intake		Exhaust Temperature Rise	Corrective Action	Reference Page
		Engine Does Not Start.			Exhaust Color	During Work					During Idling	During Work Operation				Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Water	Low Oil Pressure	Excessive Blow-by Gas	Overheat	Low Water Temperature	Pressure Drop	Pressure Rise			
		Engine Starts But Stops Soon.		None	Ordinary	White	Black																				
		Exhaust Smoke		Little	White	White	Black																				
				Much																						
Turbocharger	Fouled Blower						O																			Wash the Blower.	
	Waste Gate Malfunction				O	O																				Disassemble and Inspect.	
	Worn Radial Bearing				O	O																				Disassemble and Inspect.	
Engine Coolant System	Excessive Radiator Cooling					O									O						O					Replace Thermostat.	*See Disassembly of Engine Coolant Pump on page 207.*
	Insufficient Radiator Cooling				O																O				O	Replace Thermostat or Check for Loose Fan Belt.	*See Disassembly of Engine Coolant Pump on page 207 or Check and Adjust Cooling Fan V-Belt on page 47.*
	Insufficient Engine Coolant Level				O																O				O	Check Water Leakage from Engine Coolant System.	*See Engine Coolant System Check on page 205.*
	Cracked Water Jacket																O	O			O					Repair or Replace.	*See Disassembly of Engine Coolant Pump on page 207.*
	Stretched Fan Belt				O																O				O	Adjust the Belt Tension.	*See Check and Adjust Cooling Fan V-Belt on page 47.*
	Defective Thermostat					O	O														O	O				Check or Replace.	*See Disassembly of Engine Coolant Pump on page 207.*
Engine Oil System	Incorrect Engine Oil	O	O		O											O		O	O	O						Use Correct Engine Oil.	*See Engine Oil Specifications on page 16.*
	Engine Oil System Leakage															O			O							Repair.	*See Disassembly of Oil Pump on page 216.*
	Insufficient Delivery Capacity of Trochoid Pump																		O							Check and Repair.	*See Disassembly of Oil Pump on page 216.*
	Clogged Engine Oil Filter																		O	O						Clean or Replace.	*See Replace Engine Oil and Engine Oil Filter on page 45.*
	Defective Pressure Regulating Valve																		O							Clean, Adjust or Replace.	*See Disassembly of Oil Pump on page 216.*
	Insufficient Engine Oil Level		O																O							Add Correct Engine Oil.	*See Adding Engine Oil on page 17.*
	Overfilled Engine Crankcase																		O							Check Engine Oil	*See Checking Engine Oil on page 17.*

Trouble Symptom / Cause		Starting Problem				Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Excessive Engine Vibration	Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Excessive Blow-by Gas	Engine Coolant		Air Intake		Exhaust Temperature Rise	Corrective Action	Reference Page
		Engine Does Not Start.	Engine Starts But Stops Soon. Exhaust Smoke: None	Exhaust Smoke: Little	Exhaust Smoke: Much	Exhaust Color: Ordinary	Exhaust Color: White	Exhaust Color: Black	During Work: White	During Work: Black				During Idling	During Work Operation				Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Water	Low Oil Pressure		Overheat	Low Water Temperature	Pressure Drop	Pressure Rise			
Fuel System	Stop Solenoid Failure	O		O																									Check and Replace	*See Stop Solenoid on page 142.*
	Too Early Timing of Fuel Injection Pump								O	O	O					O													Check and Adjust.	*See Checking and Adjusting Fuel Injection Timing on page 157.*
	Too Late Timing of Fuel Injection Pump						O	O	O	O								O										O	Check and Adjust.	*See Checking and Adjusting Fuel Injection Timing on page 157.*
	Incorrect Diesel Fuel					O	O	O	O	O			O																	Use Correct Fuel Oil.	*See Diesel Fuel Specifications on page 12.*
	Water in Fuel System	O			O		O		O				O	O	O															Draining the Fuel Filter.	*See Drain Fuel Filter / Water Separator on page 48.*
	Clogged Fuel Filter	O	O			O																								Clean or Replace.	*See Clean Fuel Filter / Water Separator on page 57.*
	Air in Fuel System	O	O			O																								Bleed the Air.	*See Priming the Fuel System on page 15.*
	Clogged or Cracked Fuel Line	O	O			O																								Clean or Replace.	
	Insufficient Fuel Supply to Fuel Injection Pump	O	O			O																								Check the Fuel Tank Cock, Fuel Filter, Fuel Line, and Fuel Feed Pump.	
	Uneven Injection Volume from Fuel Injection Pump						O	O	O	O			O	O	O	O													O	Check and Adjust.	*See Testing of Fuel Injectors on page 164.*
	Excessive Fuel Injection Volume									O								O	O				O	O			O	O	Check and Adjust.	*See Testing of Fuel Injectors on page 164.*
	Poor Spray Pattern from Fuel Injection Nozzle						O	O	O	O			O	O	O	O		O												Check and Adjust.	*See Testing of Fuel Injectors on page 164.*
	Priming Failure	O																												Foreign Matter Trapped in the Valve Inside the Priming Pump (Disassemble and Clean).	*See Fuel System Components on page 147.*
	Clogged Strainer at Feed Pump Inlet					O																								Clean the Strainer.	
Air / Exhaust Gas System	Clogged Air Filter				O			O		O			O													O				Clean Air Filter.	*See Clean Air Cleaner Element on page 53.*
	Engine Used at High Temperatures or at High Altitude							O		O								O						O		O				Study Output Drop and Load Matching.	
	Clogged Exhaust Pipe							O		O			O																O	Clean Exhaust Pipe.	
Electrical System	Starting Motor Defect	O																												Repair or Replace Stater Motor.	*See Starter Motor on page 225.*
	Alternator Defect	O																												Repair or Replace Alternator.	
	Open-Circuit in Wiring	O																												Repair Open Circuit.	
	Battery Voltage Drop	O																												Inspect and Change the Battery.	*See Check Battery on page 50.*

Wiring Diagram

Note: The following wiring diagram is “representative” of a common installation using a Yanmar engine. The actual installation may be equipped with a variety of electrical components and wiring harnesses. Contact the machine manufacturer for specific information.

4TNV98 Engine



4TNE98 Engine